SECRET

NOTICES

SECURITY MARKINGS

Classification

This document is classified SECRET in accordance with paragraph 10, AFR 205-1A.

THIS DOCUMENT CONTAINS INFORMATION AFFECTING THE NATIONAL DEFENSE OF THE UNITED STATES, AS SUCH INFORMATION IS DEFINED IN PARAGRAPH 10, AFR 205-1, AND WITHIN THE MEANING OF THE ESPIONAGE LAWS (TITLE 18, U.S.C., SECTIONS 793 AND 794). THE TRANSMISSION OR REVELATION OF ITS CONTENTS IN ANY MANNER TO ANY UNAUTHORIZED PERSON IS PROHIBITED BY LAW. IT [illegible] USED, SAFEGUARDED, AND ACCOUNTED FOR AS DIRECTED BY AFR 205-1, AS AMENDED.

SPECIAL HANDLING REQUIRED. NOT RELEASABLE TO FOREIGN NATIONALS. The information contained in this document will not be disclosed to foreign nations or their representatives.

DISSEMINATION NOTICE

Dissemination of this document outside the United States Air Force is prohibited without prior approval of the FORECAST Special Project Office of Hq AFSC (SCGF).

AVAILABILITY NOTICE

Copies have not been placed in the DDC collection. Address all requests for copies to FORECAST Special Project Office, Hq AFSC (SCGF), Andrews AFB, Md. 20331.

REPRODUCTION NOTICE

Reproduction in whole or in part is prohibited without permission of FORECAST Special Project Office, Hq AFSC (SCGF).

DISPOSITION NOTICE

DO NOT return this copy. When no longer of use, destroy in accordance with pertinent security regulations and forward, within five working days of destruction, a certified true copy of the destruction certificate to FORECAST Special Project Office, Hq AFSC (SCGF), Andrews AFB, Md. 20331.

*This page is marked SECRET in accordance with paragraph [illegible], AFR 205-1. However, its actual classification is UNCLASSIFIED.

SECRET

UNITED STATES AIR FORCE

PROJECT FORECAST

INTELLIGENCE AND RECONNAISSANCE

REPORT

VOL II

JANUARY 1964

SECRET

[illegible]

This is the Report of the Intelligence and Reconnaissance Panel Chairman to the Director of Project FORECAST. As such it contains the findings and recommendations of the Panel as approved by the Chairman, but does not represent the opinions of the Project FORECAST Director except as findings of this Panel are reflected in his Final Report. Specific dates and figures in this report concerning funds, manpower, or inventory are to be treated as illustrative only and not as program planning information.

O. J. RITLAND
Major General, USAF
Chairman, Intelligence and
Reconnaissance Panel
Project FORECAST

FOREWORD

In order to ensure its maximum flexibility and utility, the Project FORECAST Intelligence and Reconnaissance Panel Final Report has been published in the following three separately bound volumes:

Volume I	Section I.	Intelligence and Reconnaissance Report Summary.	Top Secret, Limited Distribution
Volume II	Section II.	Intelligence and Reconnaissance Technology	Secret
Volume III	Section III.	Supporting Data	Top Secret, Restricted [illegible]
	Annex A	[illegible]	[illegible]
	Annex B	Intelligence Operations	
	Annex C	[illegible]	
	Annex D	Supplementary Material	

Section II of the overall Intelligence and Reconnaissance Panel Final Report is presented in this document. This material was prepared in conjunction with the reconnaissance systems analyses that were conducted by the panel.

ABSTRACT

This document presents an [illegible] of the photographic, electro-optic, IR/UV, radar, [illegible] sensor, data-transmission, data [illegible] information storage [illegible] and sensor-integration [illegible] relationships of their present [illegible] problem areas, and [illegible] requirements to the [illegible] Unusual sensors are [illegible], and future [illegible] range needs are outlined. [illegible] particularly significant [illegible] development projects, and [illegible] five [illegible] new facilities and four new types of test [illegible].

VOLUME [illegible]

CONTENTS

FOREWORD . . . . II-iii

ABSTRACT . . . . II-[illegible]

II. INTELLIGENCE AND RECONNAISSANCE TECHNOLOGY II-1

A. INTRODUCTION II-1

1. Purpose and Scope II-1

2. Approach II-1

3. Present Program II-2

4. Trends II-2

5. Overall Technical Objective and [illegible] Problem II-3

6. Recommendations . . . . II-[illegible]

B. PHOTOGRAPHY II-4

1. State-of-the-Art II-4

2. Trends . . . . II-[illegible]

a. Night and Low-Light-Level Photo Requirements . . . . II-[illegible]
b. Electromagnetic Spectrum . . . . II-[illegible]
c. Atmospheric Turbulence and Haze . . . . II-[illegible]
d. Photographic Optics . . . . II-[illegible]
e. Image Motion Compensation ([illegible]) II-10
f. Receptors . . . . II-[illegible]

3. Problems . . . . II-[illegible]

4. Emphasis . . . . II-[illegible]

a. Exploratory Development . . . . II-[illegible]
b. Advanced Development . . . . II-[illegible]

CONTENTS (Continued)

		Page
C.	ELECTRO-OPTICS	II-19
	1. State-of-the-Art	II-19
	2. Trends	II-22
	3. Problems	II-[illegible]
	4. Emphasis	II-[illegible]
	a. Exploratory Development	[illegible]
	b. Advanced Development	[illegible]
D.	INFRARED/ULTRAVIOLET	II-[illegible]
	1. State-of-the-Art	II-[illegible]
	a. Detectors	[illegible]
	b. Cooling Techniques	[illegible]
	c. Window Materials	[illegible]
	d. IR Reconnaissance Subsystems	[illegible]
	e. Ultraviolet	[illegible]
	2. Trends	[illegible]
	a. Detectors	II-32
	b. Cooling	II-[illegible]
	c. Windows	II-[illegible]
	d. Subsystems	II-[illegible]
	e. UV Techniques	II-[illegible]
	3. Problems	II-[illegible]
	4. Emphasis	II-[illegible]
	a. Exploratory Development	[illegible]
	b. Advanced Development	II-36

SECRET

CONTENTS (Continued)

Page

[illegible]. HIGH-RESOLUTION GROUND MAPPING RADARS . . . . [illegible]

1. State-of-the-Art . . . . [illegible]

a. High-Resolution Aircraft Radars . . . . [illegible]
b. Airborne Moving Target Indicator (AMTI) . . . . . . [illegible]

2. Trends . . . . [illegible]

a. High-Resolution Ground Mapping (Coherent) Radars (Side-Looking) . . . . [illegible]
b. Airborne Moving Target Indicator . . . . [illegible]

3. Problems . . . . [illegible]

4. [illegible] . . . . [illegible]

a. Exploratory Development . . . . [illegible]
b. Advanced Development . . . . [illegible]

[illegible]. PASSIVE ELECTROMAGNETIC SENSORS . . . . [illegible]

1. State-of-the-Art . . . . [illegible]

a. Airborne Electronic Intelligence (ELINT) System Sensors (Ferret) . . . . [illegible]
b. Airborne Communications Intelligence (COMINT) System Sensors . . . . [illegible]
c. Ground-Based ELINT Sensors . . . . [illegible]
d. Ground-Based COMINT Sensors . . . . [illegible]

2. Trends . . . . [illegible]

a. General Technology Trends . . . . [illegible]
b. Location Accuracy . . . . [illegible]
c. Antennas . . . . [illegible]
d. Receivers . . . . [illegible]
e. Recording . . . . [illegible]
f. Displays . . . . [illegible]
g. Adaptive Systems Organization . . . . [illegible]

GROUP 1
SECRET

CONTENTS (Continued)

	Page
3. Problems	II-57
4. Emphasis	II-58
a. Exploratory Development	II-58
b. Advanced Development	II-62
G. DATA TRANSMISSION	II-6[illegible]
1. State-of-the-Art	II-6[illegible]
a. Existing Capability	II-6[illegible]
b. Development Programs Now in Progress	II-6[illegible]
2. Trends	II-66
3. Problems	II-66
a. Wideband Data Transmission	II-66
b. Secure Voice Communications	[illegible]
c. Operational Incompatibility	[illegible]
d. Electro-Optical Converter	[illegible]
e. Antenna Stabilization	[illegible]
f. Cryptographic Security	[illegible]
g. Manual Versus Automatic	[illegible]
h. Air-to-Ground Photo Transmission	[illegible]
4. Emphasis	II-72
a. Exploratory Development	II-72
b. Advanced Development	II-73
H. DATA PROCESSING	II-74
1. State-of-the-Art	II-74
a. Photo Reproduction Materials	II-74
b. High-Acuity Photo Reproduction	II-74
c. Photo-Processing in an Austere Environment	II-74

CONTENTS (Continued)

Page

d. In-Flight Photo-Processing Techniques . . . II-76
e. Electronic Signal Image Recording . . . II-76
f. Special Photo-Processing Techniques . . . II-76
g. Image-Data Processing (Electronic and Optical) . . . II-76
h. SIGINT (ELINT, COMINT, and [illegible]) Data Processing . . . II-77

2. Trends . . . II-77

a. Reproduction Materials . . . II-77
b. High-Acuity Reproduction . . . II-77
c. Processing in an Austere Environment . . . II-79
d. In-Flight Processing . . . II-79
e. Electronic Signal Image Recording . . . II-79
f. Special Photo-Processing Techniques . . . II-79
g. Image-Data Processing (Electronic and Optical) . . . II-81

3. Problems . . . II-81

a. Photographic Reproduction Materials . . . II-81
b. High-Acuity Reproduction . . . II-81
c. Processing in Austere Environment . . . II-81
d. In-Flight Processing . . . II-82
e. Electronic Signal Image Recording . . . II-82
f. Special Processing Techniques . . . II-83
g. Image-Data Processing . . . II-83

4. Emphasis . . . II-83

a. Exploratory Development . . . II-83
b. Advanced Development . . . II-84

I. DATA EXTRACTION . . . II-85

1. State-of-the-Art . . . II-85

a. Image-Data Extraction . . . II-85
b. SIGINT Data Extraction . . . II-86
c. Data Correlation . . . II-88

SECRET

CONTENTS (Continued)

Page

2. Trends II-92

a. Image-Data Extraction II-92
b. SIGINT Data Extraction II-97
c. Data Correlation II-98

3. Problems II-99

a. Image Data Extraction II-99
b. SIGINT Data Extraction II-100

4. Emphasis II-102

a. Exploratory Development II-102
b. Advanced Development II-103

III. INFORMATION DISSEMINATION, STORAGE, AND RETRIEVAL . . . II-105

1. State-of-the-Art II-105

a. Dissemination II-105
b. Data Storage II-107
c. Objective Storage II-113

2. Trends II-115

a. Dissemination II-115
b. Data Storage II-115
c. Object Storage II-124

3. Problems II-127

a. Dissemination II-127
b. Input Processing II-127
c. Retrieval II-128

4. Emphasis II-128

a. Exploratory Development II-129
b. Advanced Development II-130

[illegible] Contents (Continued)

Page

K. SENSOR INTEGRATION . . . . [illegible]

1. State-of-the-Art . . . . III-1[illegible]

2. Trends . . . . III-1[illegible]

3. Problems . . . . III-1[illegible]

4. Emphasis . . . . III-1[illegible]

a. Exploratory Development . . . . III-1[illegible]
b. Advanced Development . . . . III-1[illegible]

L. UNUSUAL SENSORS III-138

1. Sensor Types III-138

2. Recommendations III-139

M. RESOURCES . . . . III-14[illegible]

1. High-Quality Optical Glass . . . . III-14[illegible]

a. Security Aspects . . . . III-14[illegible]
b. Development of American Capability . . . . III-14[illegible]
c. General Plan . . . . III-14[illegible]

2. Air Force Laboratory Facilities . . . . III-14[illegible]

a. Radiation Science Laboratory . . . . III-14[illegible]
b. Optical Science Facility . . . . III-14[illegible]
c. Electromagnetic Facility . . . . III-14[illegible]
d. Data Extraction Analysis Reduction Facility . . . . III-14[illegible]

3. Ground-Test Range Facilities . . . . III-14[illegible]

a. Calibration Range . . . . [illegible]
b. COIN and Limited-War Environmental Reconnaissance Ranges . . . . III-14[illegible]
c. Low-Altitude Photogrammetric Range . . . . III-14[illegible]
d. Simulated Operational Test . . . . III-14[illegible]

APPENDIX A - GLOSSARY . . . . [illegible]

[illegible]

Figure | Page

II-1. Approximate Resolution Trend, [illegible] Subsystem II-9

II-2. Approximate Angular Resolution Trend, Photographic Subsystems II-11

II-3. Error Trend, Angular Steadiness, [illegible], and Image Motion Control II-12

II-4. Approximate Resolving Power and Exposure Index Trends, Photographic Sensitized Materials II-13

II-5. Approximate Resolution Trend, Electro-Optical Subsystems II-21

II-6. Approximate Exposure Index and Resolving-Power Trends, Image-Orthicon and Vidicon-Type Tubes II-23

II-7. Approximate Exposure Index and Resolving Power Trends, Electro-Optical Photo [illegible] II-24

II-8. Detectivity (D*) Versus Wavelength of Selected Detectors II-27

II-9. Approximate Resolution Trend, Infrared Subsystems II-34

II-10. High-Resolution Radar Technology Trends . . . . II-4[illegible]

II-11. Miniaturization Trends in Electronic Equipment II-52

II-12. Weight Trends in Electronic Equipment II-53

II-13. Reliability Trends in Electronic Equipment . . . . II-5[illegible]

II-14. Time Required to Transmit One 9- x 9-in. Frame at a Transmission Rate of 100 Megabits/sec . . . . II-[illegible]

II-15. Approximate Low-Contrast Resolution Trend for Reproduction Throughout Generations of Continuous-Tone Negatives II-78

[illegible]

Figure		Page
II-16.	Approximate [illegible] Trend for Reconnaissance [illegible]	[illegible]
II-17.	Data Extraction Trend	II-[illegible]
II-18.	Simplified Typical [illegible] of an Information Distribution System	II-1[illegible]
II-19.	Typical Data-File Update Process	[illegible]
II-20.	Data-Retrieval Process	II-112
II-21.	Computer Storage Evolution	II-113
II-22.	Approximate Location-Error Trend	II-1[illegible]

SECRET

Table		Page
II-1.	Characteristics for Cesium Silver Family Emissions	II-6
II-2.	Reconnaissance Receptor Materials	[illegible]
II-3.	Performance of Elemental Detectors	II-28
II-4.	Typical IR Image Tubes	II-29
II-5.	Wideband Transmission Media	II-66
II-6.	Reconnaissance Reproduction Materials	II-75
II-7.	Current State-of-the-Art, Data Processing Equipment	II-108
II-8.	Projected State-of-the-Art, Data Processing Equipment	II-120
II-9.	Projected State-of-the-Art, Data Processing Techniques	II-122
II-10.	Projected State-of-the-Art, Document and Photo Handling Technology	II-126

[illegible]

I. INTRODUCTION

1. Purpose and Scope

The objectives of this report are:

1) To assess the [illegible] in the technologies which support intelligence and reconnaissance activities.

2) To predict the trends of possible state-of-the-art technological advances during the forecast time period.

3) To determine current technical problem areas.

4) To recommend changes to current exploratory and advanced development efforts.

5) To recommend new advanced development programs to optimize intelligence and reconnaissance activities.

Fundamental intelligence and reconnaissance technologies considered in this report cover data collection, transmission, processing and [illegible] and information storage and dissemination. The collection technology includes photography and electro-optic, infrared, radar, electromagnetic, and unusual sensors.

2. Approach

For purposes of the following discussion, the intelligence and reconnaissance technology subject area has been divided into the 12 major topics of photography, electro-optics, infrared (IR) and [illegible], radar, passive electromagnetic (EM) sensors, data transmission, data processing, data extraction, information storage, dissemination, and retrieval, sensor integration, unusual sensors, and resources. With the exception of unusual sensors and resources, each of these technologies is [illegible] with respect to state-of-the-art, trends, problem areas, and exploratory and advanced development. Consideration of unusual sensors is limited to a partial listing of potentially fruitful areas for investigation together with recommendation for the continuing of more complete evaluation efforts. Future facility and test-range costs are outlined in the resources analysis.

SECRET

3. [illegible] Problem

The [illegible] uses of aeronautical reconnaissance [illegible] during the [illegible] time period resulted in [illegible] the Air Force intelligence and reconnaissance capability. [illegible] the scope of effort in equipment development [illegible] has been broad enough. However, owing to lack of emphasis, certain developments have not achieved desired status, such as, for example, night and bad-weather sensors. Daylight photography is fairly well advanced. Electro-optics and infrared techniques have [illegible], but exploitation of their capability for [illegible] use is just beginning to be investigated. Radar is the only bad-weather imaging sensor currently available and needs state-of-the-art advance to provide more [illegible] information. Non-imaging sensors for signal intelligence (SIGINT) need improvement to keep up with foreign technological developments, and many other sensors of the unusual category are just beginning to be explored.

Next to nighttime and bad-weather data collection, the state-of-the-art in handling the vast amounts of data which can be collected is the area needing greatest advance. In all present systems, human interpretation, data processing, transmission, storage, retrieval, and dissemination are bottlenecks. More work in terms of systems and subsystems [illegible] synthesis and analysis is needed to enhance the [illegible]. System integration, with emphasis on the final product, [illegible] to be understood and exploited.

4. Trends

In the next few years night and low-light-level photography will be improved sufficiently to be useful around the clock in clear weather. Electro-optic and infrared techniques will permit target detection through many types of camouflage in clear weather at night as well as in daytime. Radar can be improved to provide fine detail and some penetration, even under relatively complete foliage cover. SIGINT data collection can be improved to cover most of the useful spectra and provide instantaneous emitter-location information. Data processing can be improved in fidelity and response to keep pace with advances in sensor technology. Data extraction can be automated to some extent. However, inasmuch as the human interpreter cannot be replaced by machines, there is a limit to the degree that response time can be reduced and the accuracy improved through automation. Nevertheless, electronic data processing can be added to information storage and dissemination systems to improve the response time and accuracy of information to an acceptable level.

5. Overall Technical Objective and Associated Problems

The overall technical objective in support of the intelligence and reconnaissance program is directed to obtain an around-the-clock sensing capability coupled with a near-real-time readout to the user. Major technical problems stemming from this objective are as follows:

1) Sensitivity of passive sensors is inadequate and/or sources of supplementary energy are insufficient.

2) Time cycles from sensing to the user are too long.

3) Quality and speed of interpretation need improvement.

4) Capability to integrate two or more sensors into a usable subsystem is lacking.

5) Improved resolution of all imaging sensors and improved sensitivity of all non-imaging sensors is needed.

6) Capability to operate under adverse environmental conditions is inadequate.

6. Recommendations

The following actions in support of intelligence and reconnaissance technology advancement are recommended:

1) Increase funding for exploratory development by 82 percent over present funding for a total of $3[illegible] million per year.

2) Increase advanced development to a peak of $[illegible] million by FY 66.

3) Construct five new facilities and four new types of test ranges at a cost of approximately $17,[illegible].

SECRET

SECURITY NOTICE

Classification

This document is classified SECRET in accordance with paragraph [illegible] [illegible]

THIS DOCUMENT CONTAINS INFORMATION AFFECTING THE NATIONAL DEFENSE OF THE UNITED STATES, AS SUCH INFORMATION IS DEFINED IN [illegible] AND WITHIN THE MEANING OF THE ESPIONAGE LAWS (TITLE 18, U.S.C., SECTIONS 793 AND 794). THE TRANSMISSION OR REVELATION OF ITS CONTENTS IN ANY MANNER TO ANY UNAUTHORIZED PERSON IS PROHIBITED BY LAW. IT [illegible] [illegible] SAFEGUARDED, AND ACCOUNTED FOR AS [illegible]

SPECIAL HANDLING REQUIRED. NOT RELEASABLE TO FOREIGN NATIONALS. The information contained in this document will not be disclosed to foreign nations or their representatives.

DISSEMINATION NOTICE

Dissemination of this document outside the United States Air Force is prohibited without prior approval of the FORECAST Special Project Office of Hq AFSC (SCGF).

AVAILABILITY NOTICE

Copies have not been placed in the DDC collection. Address all requests for copies to FORECAST Special Project Office, Hq AFSC (SCGF), Andrews AFB, Md., 20331.

REPRODUCTION NOTICE

Reproduction in whole or in part is prohibited without permission of FORECAST Special Project Office, Hq AFSC (SCGF).

DISPOSITION NOTICE

DO NOT return this copy. When no longer of use, destroy in accordance with pertinent security regulations and forward, within five working days of destruction, a certified true copy of the destruction certificate to FORECAST Special Project Office, Hq AFSC (SCGF), Andrews AFB, Md. 20331.

---

*This page is marked SECRET in accordance with paragraph [illegible], AFR [illegible]. However, its actual classification is UNCLASSIFIED.

SECRET

[illegible]

B. Illumination [illegible]

1. [illegible]

Photographic reconnaissance today [illegible] designed to [illegible] daytime [illegible] at low light levels. The illumination [illegible] the most important factor in a photographic system [illegible] resolution [illegible]. To extend this capability [illegible] improved illumination [illegible] high-resolution lenses, and faster films [illegible] a limited low-altitude capability [illegible] be obtained without high angular resolution [illegible] and fast films, a capability also exists of an approximately [illegible] resolution at a 1000-ft altitude [illegible] amplification techniques have increased this capability [illegible] levels, but much more room for improvement [illegible].

At starlight and lower illumination levels, [illegible] for really adequate photography are [illegible] be provided. Technology for use of the following types of illumination exists at the present time:

1) Flashbombs up to approximately 30,000 ft.

2) Flash cartridges from approximately 1000 to 7000 ft.

3) Flash lamps up to approximately 2000 ft.

4) Flash bulbs up to approximately 5000 ft.

5) High-pressure mercury vapor lamps ([illegible] light) up to approximately 5000 ft.

6) Magnesium flares up to approximately 3000 ft.

Inasmuch as most of the foregoing techniques are not suitable at high speeds, work is underway on adapting lasers for this purpose. Also, more study of new illuminants is required.

Although photography today is considered a prime sensor in its own right, it is also a valuable technique that lends itself to incorporation into other reconnaissance-sensor subsystems for data processing, recording,

[illegible]

No unconventional [illegible] to permit the [illegible] [illegible] due to the fact that [illegible] of adequate photometric sensitivity [illegible] image quality. [illegible] are listed in Table [illegible].

Two other [illegible] clearly [illegible] systems which should be mentioned [illegible] readout of photographs [illegible] chemical and electronic [illegible] systems.

2. Trends

a. High and Low-Intensity-Level Photo Reconnaissance

In the next few years high and low-intensity-level photo reconnaissance will be improved in the whole photo system. The most significant improvement will be in connection with light sources [illegible] laser developments, particularly [illegible] [illegible] other exciting possibilities [illegible] sources than those presently available [illegible] the rapid advances in illumination [illegible] rate of progress there will [illegible] reason to believe that light sources [illegible] at high altitudes and high speed will not be available by approximately 1970. When coupled with [illegible] provide a photo capability 60 percent of the time. [illegible] techniques also will play an important [illegible] IR resolution trends for purely passive image intensification [illegible] amplification with no auxiliary illumination [illegible] Prospects are not encouraging for large resolution at high altitudes and high speed, and high resolution at low altitude [illegible] because of the requirement for long exposure time.

b. Electromagnetic Spectrum

A trend toward utilizing more of the electromagnetic spectrum for photography will be apparent. [illegible] basis for establishing [illegible] capability in [illegible] an effective means for obtaining target keys at low altitude. [illegible] IR, perhaps out to 1.5 microns, will be useful in advanced camouflage detection film and target keys.

SECRET

Table III-2. Reconnaissance [illegible]

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Figure II-1. Approximate Resolution Trend
Low-Light-Level Subsystem

c. Atmospheric Turbulence and Haze

A better understanding of both natural and induced atmospheric turbulence and of haze, particularly as it applies to long-range oblique photography (LOROP), will be acquired in the next [illegible] years. It appears very likely that by 1970 image data processing [illegible] which will [illegible] the overcoming of many adverse atmospheric effects will be [illegible]. Possibility also exists for achieving the very high ground resolution performance indicated in Figure II-2 without building lenses larger than 100 in. in diameter.

d. Photographic Optics

Photographic optics will advance within the next five years to provide near diffraction-limited lenses as fast as f/[illegible]. The [illegible] special applications with apertures to [illegible] and [illegible] in. [illegible] surfaces and catadioptric designs [illegible] modification will further aid in achieving the [illegible] indicated in Figure II-2. The trend after 1970 [illegible] will be dependent upon the effort [illegible] in both [illegible] and [illegible], the success of present exploratory development [illegible] and appropriate [illegible] requirements. [illegible] for very high resolution will be [illegible] for space reconnaissance.

e. Image Motion Compensation (IMC)

The trends in IMC are indicated in Figure II-3. Success in achieving these predictions will to a large degree determine the extent to which the predictions indicated in Figures II-1 and II-2 will be attained. [illegible] IMC techniques providing [illegible], [illegible], and [illegible] control are essential to achieving acceptable [illegible] of strip cameras, panoramic cameras, and other scanning-type sensors.

f. Receptors

A progressive upgrading of gelatin silver halide receptors will be continued during the 1965/1975 time period. This work is being done by photographic film manufacturers without government sponsorship. The resolving-power trends versus exposure indexes for these materials are shown in Figure II-4. By the 1965/1975 time period, unconventional materials will be replacing the gelatin silver halides in special high-acuity high-altitude reconnaissance systems. Vacuum-evaporated coatings of monomolecular silver bromide and electrooptic tapes will be the first

Figure II-2. Approximate Angular Resolution Trend, Photographic Systems

SECRET

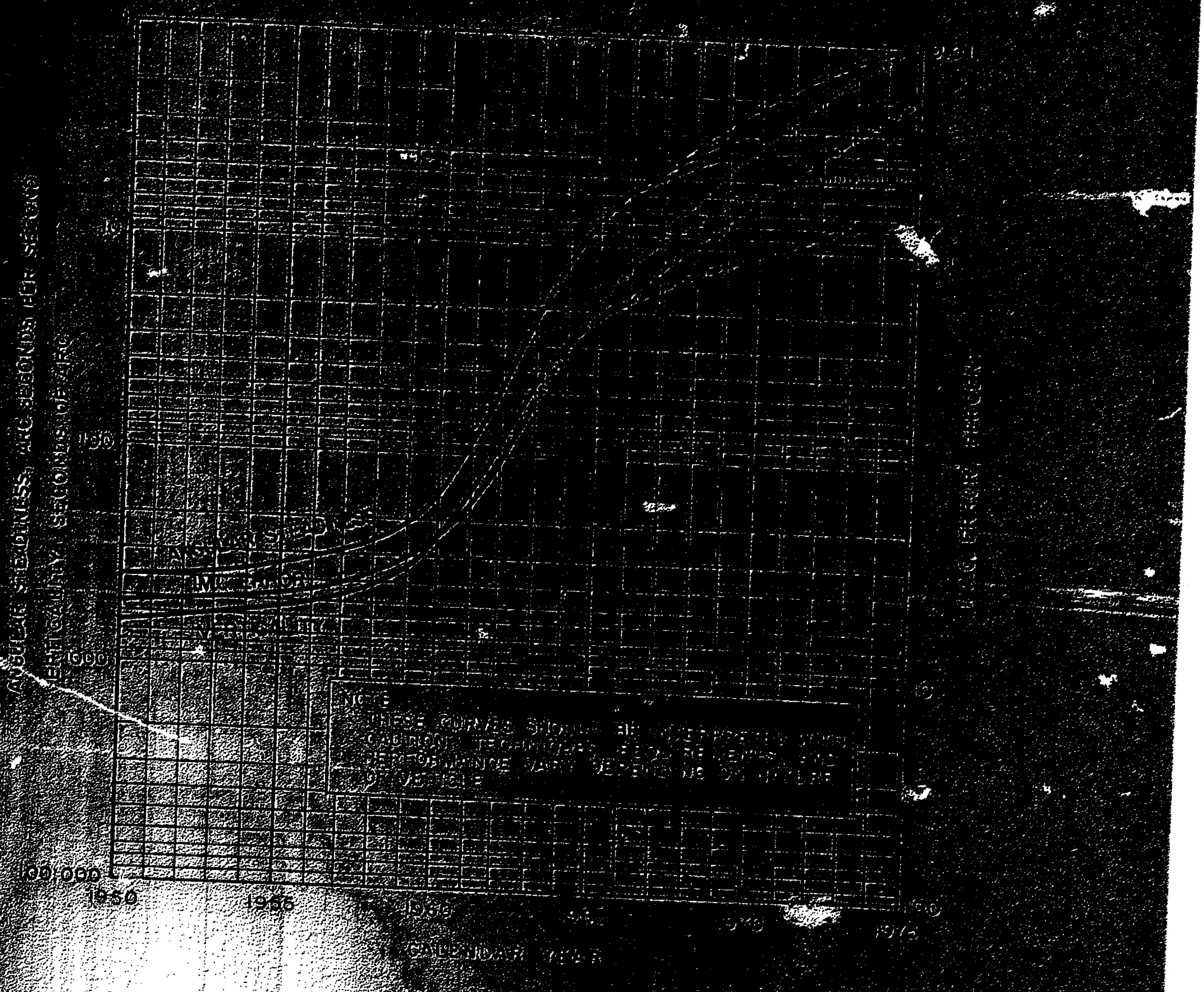


Figure II-3. Error Trend, Angular Steadiness, Verticality, and Image Motion Control

Figure II-4. Approximate Resolving Power and Exposure Index Trends, Photographic Sensitized Receptors

c) Improvements [illegible] particularly in aspheric surfaces.

d) Development of [illegible] for large lens [illegible] eliminate [illegible] large lenses.

e) Development of techniques for handling large [illegible] optics to overcome [illegible] focus problems.

5) Refining [illegible] techniques and [illegible] to improve IMC and camera [illegible] longer exposure [illegible] light-level, high-resolution, and [illegible] problems.

6) Identifying and [illegible] receptors to increase [illegible] shift reception [illegible] achieve panchromatic [illegible] Additional desirable [illegible] radiation resistance, [illegible] ability to form visible [illegible] problem in producing [illegible] silver halides is the [illegible] crease in sensitivity without [illegible] even their inherent [illegible] radiation may be [illegible] by sensitizing [illegible] to exposure and processing [illegible]

4. Emphasis

The area in photography most urgently requiring emphasis is [illegible] low light-level reconnaissance, [illegible] lent that achievable in bright day light [illegible] be necessary for research and development to continue in all phases of photographic technology [illegible] performance indicated in Figure II-2 is to be achieved. More subsystem analyses also will be required to [illegible] weak links in the photo-reconnaissance chain as development [illegible]

All factors contributing to the present state of the photographic art will need continued upgrading, particularly the areas of atmospheric research, optics, IMC, camera controls, and photo receptors. Goals for 1970 should be:

1) Diffraction-limited, f/[illegible] lenses in [illegible] focal lengths [illegible] to [illegible] in.

2) Very long focal length systems [illegible] and integration of [illegible].

3) Receptors with resolution on the order of 500 lp/mm.

4) High-speed receptors for low light levels.

5) More convenient receptors in terms of processing, real-time imaging, immunity to nuclear radiation, and reusability.

Methods of camera control for these new techniques as well as methods for their test and evaluation also will be required.

a. Exploratory Development

The following exploratory development programs should be undertaken:

1) Nighttime photography with [illegible] of [illegible] light sources, particularly in the [illegible] the perfection of light amplification [illegible] combination with photography should be [illegible].

2) Wide-spectrum cameras and [illegible] techniques for [illegible] target detection (CD) using broad-band [illegible] (SW) film.

3) Atmospheric studies on both [illegible] and [illegible] on haze, particularly for LOROP.

4) New lens designs, optical-glass technology, and temperature control, test, and evaluation techniques.

5) Camera controls capable of providing [illegible] pointing, focusing, shutters, and cycling rates.

6) Higher-resolution receptors, more sensitive silver-halide films, and new unconventional materials to provide real-time imaging, dry processing, nuclear resistance, reusability, and high resolution.

Photo-subsystem analysis and evaluation should be conducted on both a theoretical and experimental basis with emphasis on new analysis and measurement techniques and on optimization of tradeoffs.

Although the foregoing work is presently programmed, [illegible] on these programs should be increased by at least [illegible] $1,750,000.

B. Advanced Development

Advanced-development emphasis should be given to [illegible] photo subsystems and to [illegible] on the [illegible] of the [illegible] and refinements resulting from the above programs. The following advanced development projects are recommended:

1) Night reconnaissance photo subsystems (NRPS) utilizing [illegible] artificial illumination and [illegible] light-amplification techniques. Such systems should provide [illegible] real-time display [illegible] mode. Total cost would be on the order of $5,000,000.

(2) A high-resolution [illegible] subsystem having very high angular resolution [illegible] operating in either a strip mode [illegible] camera mode [illegible] could be used in connection [illegible] and a television-like display. [illegible] wide-angle and [illegible] could be used. [illegible] sequencing could provide [illegible] zone data extraction techniques. Total cost would be on the order of $3,000,000.

3) Low-altitude high-speed photo subsystems for use in aircraft flying below 1000 ft at speeds in excess of Mach [illegible]. Total cost would be on the order of $750,000.

4) A high-cycling-rate aerial camera for [illegible] of spectral filtration and [illegible] techniques, which would also be applicable to the low-altitude high-speed [illegible] mode. Total cost would be on the order of [illegible].

5) A multipurpose aerial camera which is capable of use in a panoramic, strip, or frame mode. Total cost would be on the order of $1,000,000.

SECRET

[illegible]

5. Methods for [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] will be required to [illegible] [illegible] [illegible] [illegible] mass production capability [illegible] possibilities of [illegible] [illegible] to absorb this cost.

C. ELECTRO-OPTICS

1. [illegible]

Electro-optical technology in the past has been associated with television-type image tubes having [illegible] scanning techniques in the visual region of the spectrum. However, recent developments have opened up the possibility of extending these techniques into the infrared and ultraviolet regions. Outputs of such devices have conventionally been displayed on cathode ray tubes [illegible] recorded on photographic film [illegible]. [illegible] outputs also have opened up the possibility of recording [illegible] on flexible belt or tape [illegible] for storage and [illegible] retrieval. This method is similar [illegible] the photoconductor replaced by a [illegible].

Another family of related [illegible] techniques and uses light sources for [illegible] illumination to enhance performance. Among light sources suitable for these applications are pulsed high-intensity light sources [illegible] to provide 3-dimensional data, [illegible] light sources such as flash bombs, cartridges, lamps and [illegible] lamps, magnesium flares, etc., and [illegible] lasers used in a scanning mode.

The discussion of photography previously presented in Section II-B also applies to electro-optical technology. Only the [illegible] are different in that they are photosensitive devices which translate light energy into electronic signals. These receptors may be classified into the following categories:

1) Photoelectric Cells – Photoelectric cells are used in electro-optical systems today in a manner similar to IR cells, usually in a scanning mode. Although they are [illegible] developed to a high degree and are practically photon-noise-limited, their application suffers from the same problems of [illegible] and frequent complexity of the scanning mode as are associated with IR systems.

2) Image Orthicons – Image-orthicon-type TV, or photoemissive tubes yield the highest quantum efficiency of any imaging device, having an equivalent American Standards Association (ASA) exposure index of approximately [illegible], which is about [illegible] times as fast as photographic film. However, they are handicapped by relatively low resolution capability of approximately [illegible]/mm, poor contrast discrimination with wide dynamic range, and small, approximately 1-in.^{2} sizes which limit coverage. These units constitute the basis of many image-amplification devices.

[illegible]

3) Vidicon - Vidicon-type [illegible] of image orthicon [illegible] with similar [illegible] resolution [illegible] to [illegible], and sensitivity is less [illegible] and exposure times [illegible] same as in the case of image orthicon tubes.

4) [illegible] very high resolution [illegible] before readout [illegible] have to nuclear [illegible] played on a CRT [illegible] produce hard copy [illegible] is achievable [illegible] mately 30 [illegible] optical subsystems [illegible] are capable of angular resolution of approximately [illegible] seconds of arc, as noted in Figure [illegible] type systems [illegible] resolution of approximately [illegible] second of arc.

5) Direct Image Tubes - Direct image tubes [illegible] scanning for readout and produce an image by the impact of high-energy focused electrons on a fluorescent screen. These electrons are emitted from a photoemissive surface [illegible] mary focus of an optical system. This technique is being employed in image intensifiers [illegible] multiple stages and fiber-optics couplers. [illegible] of this category are sensitive to [illegible] levels, with [illegible] when coupled with [illegible] film. However, resolution is not very good for reconnaissance [illegible] 20 seconds of arc [illegible] and contrast discrimination is poor, as shown previously in Figure III-1.

Electro-optical techniques provide the advantage of a real time TV-type display, although the problem of linear sweep [illegible] deterioration of geometric fidelity. Also advantageous is that the image is in electronic form, and therefore is amenable to transmission over a data link or to electronic data processing to improve quality or reduce redundancy. Readout video bandwidths of 10 to 20 [illegible] are possible. Techniques have been developed for recognizing [illegible] image characteristics such as clouds and industrial complexes for data filtering before transmission (Ref. Section II.G).

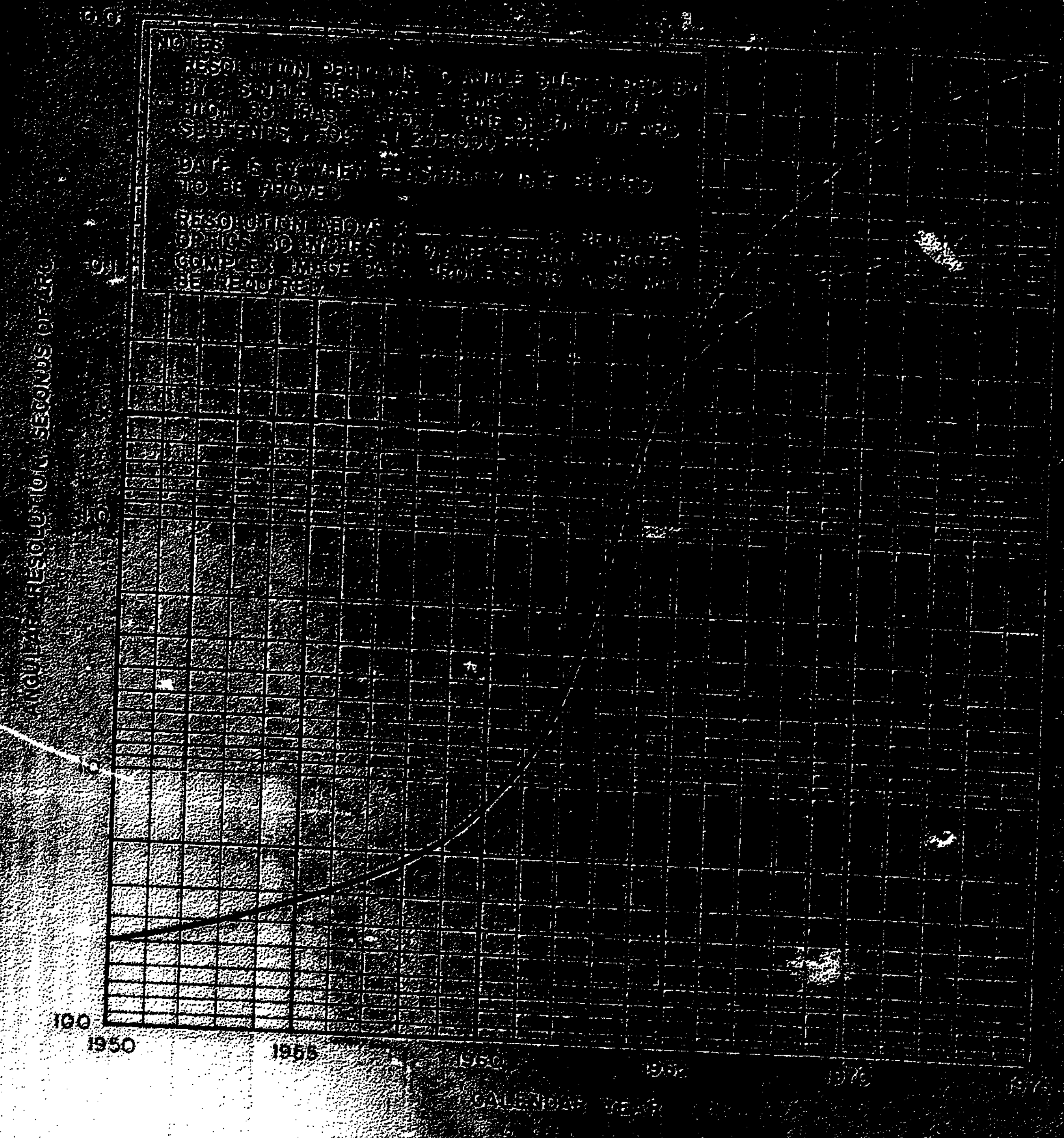


Figure II-5. Approximate Resolution Trend, Electro-Optical Subsystems

SECRET

2. Trends

Trends relating to development of electro-optical techniques and devices are illustrated in Figures II-8 and II-9, which indicate anticipated [illegible] abilities for image-orthicon-type tubes, [illegible] tape. Figure II-9 indicates anticipated performance of [illegible] subsystems which incorporate optical [illegible] controls, and image-data processors, as in photography. [illegible] performance in conjunction with [illegible] is shown in Figure II-1[illegible]. Most of these curves provide [illegible] of the possibilities beyond 1967. However, the [illegible] that time will depend on resources expended [illegible] aspects of present exploratory developments, [illegible] and requirements. A great deal is expected of the field of light sources, lasers, etc. Optical radar is a technique [illegible] possibility by 1970, and it may be possible to apply this technique to the problem of underwater submarine detection. Trends in this fast moving field are difficult to predict at this time.

3. Problems

Future development of electro-optical techniques and devices will depend to a large degree on discoveries and studies in solid-state physics. Better materials with suitable characteristics for high resolution and sensitivity, as well as techniques for controlling electron beams [illegible] small spot sizes for high resolution and [illegible] very lasers having fast pulse-repetition rates also are needed. [illegible] methods for consistently producing high-performance devices and materials is a further problem area.

4. Emphasis

a. Exploratory Development

Exploratory development on improving photo-tape resolution and sensitivity should be continued and writeout techniques for producing high-resolution hard-copy prints requires further work. Additional exploratory development to improve light-amplification and image-intensification devices and techniques should be conducted using both the image-tube and the image-orthicon approach. New techniques for image enhancement, discrimination, and data filtering with spectral and spatial filtering should be investigated. New applications of photo tape as image storage and processing techniques should be examined for application to other sensors such as IR and radar. Development of applicable laser techniques, both CW and pulsed, should be accelerated, and the search for detectors to match the single frequency of a laser light source should be emphasized.

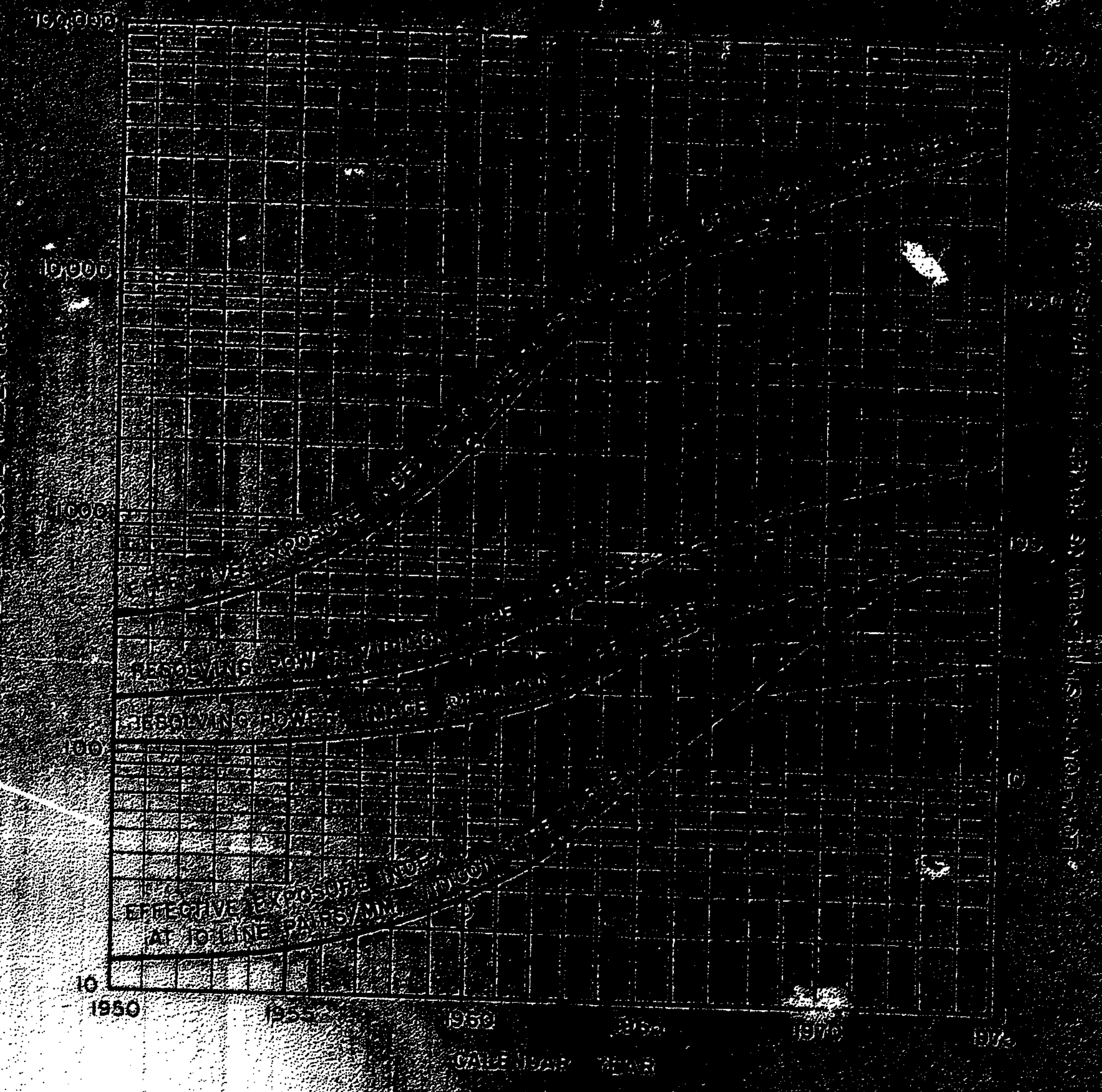


Figure II-6. Approximate Exposure-Index and Resolving-Power Trends, Image-Orthicon and Vidicon-Type Tubes

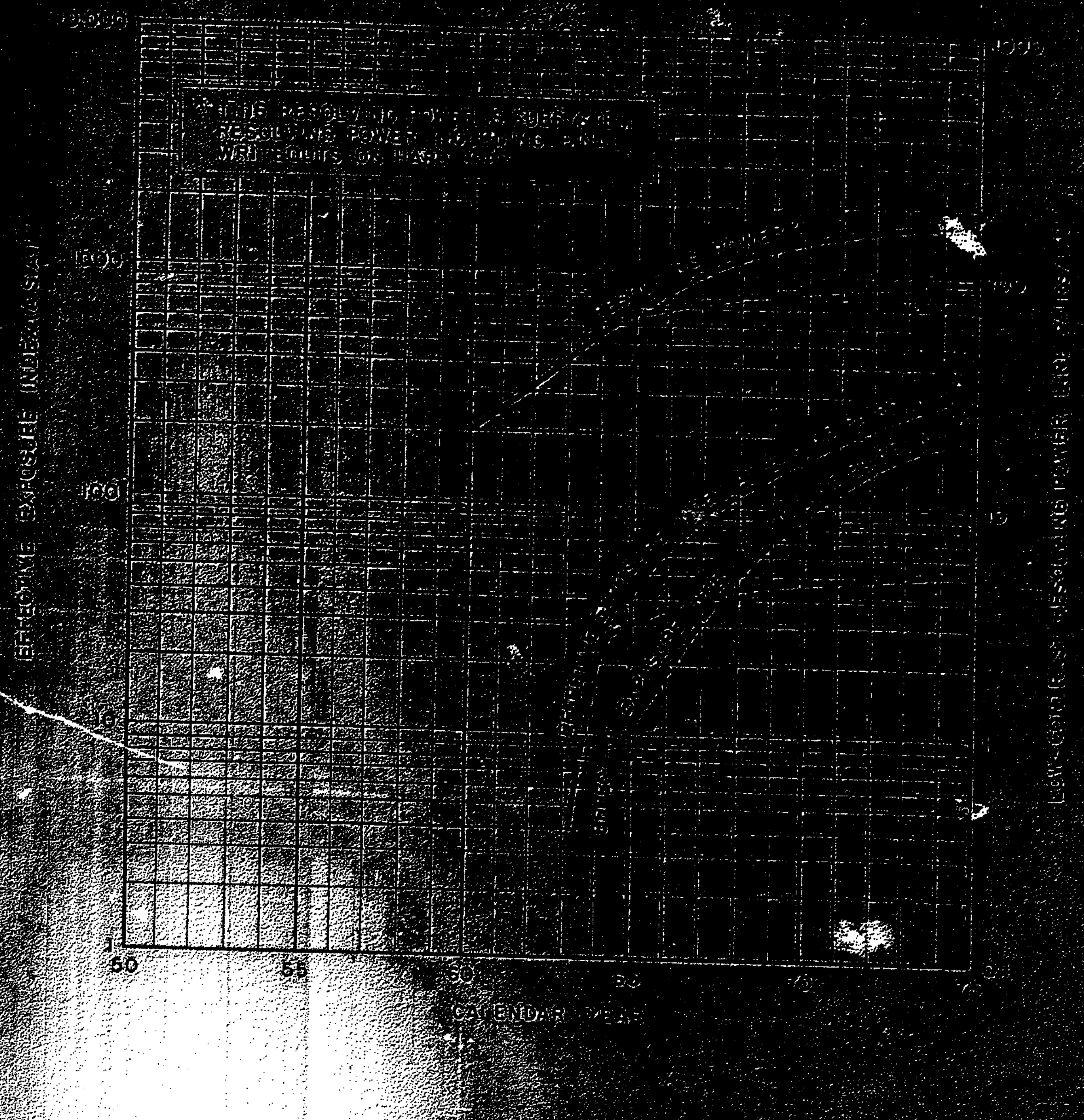


Figure II-7. Approximate Exposure Index and Resolving Power Trends, Electro-Optical Photo Tape

although work in this area is being generally pursued, funding [illegible] should be increased to at least 50 percent, or approximately $750,000.

b. Advanced Development

Investigation of the following advanced development work should be conducted on an integrated basis and should include supporting systems analyses and trade-off studies.

1) Low-light-level and night [illegible] subsystems [illegible] would provide a near-real-time capability [illegible] of recent advances in light [illegible] and artificial illumination. Perhaps a [illegible] optical radar could be employed. [illegible] presently covered in the applied research program [illegible] considered ready for advanced development. Total funding on the order of $2,000,000 will be required.

2) A photo-tape subsystem for a near-real-time capability would also provide a low-light-level [illegible]. This subsystem would have a 2.25- × 2.25-in. format, with [illegible] of approximately 50 to 100 lp/mm. Required funding will be on the order of $2,000,000.

3) The introduction of photo tape will cause major problems in manufacturing technology. Large quantities of either government or commercial resources will be required to convert photo-tape laboratory technology to the mass production capabilities required for subsystems application.

4) A real-time photo-tape camera and an optical radar system are two advanced development programs now in exploratory development that are considered achievable in FY 6[illegible] and FY 68 respectively at costs of $800,000 and $2,000,000.

D. INFRARED/ULTRAVIOLET

1. State-of-the-Art

a. Detectors

The performance of several of the more [illegible] elements [illegible] detectivity versus wavelength [illegible] Figure [illegible]. It should be noted that cooling of the elements [illegible] improve the performance [illegible] currently available [illegible] detectors and [illegible] pertinent characteristics are [illegible] Table II-[illegible]

Fabrication of these elements [illegible] has [illegible] to [illegible] extent and [illegible] arrays [illegible] ing of over twenty (20) [illegible] fabricated and tested successfully. [illegible] were as small as [illegible] in. long, 0.0033 in. wide, and [illegible] 0.0025 in. [illegible] long [illegible] been successfully [illegible] present time.

The state-of-the-art [illegible] in Table II-[illegible]. [illegible] bolometric and photoconductive [illegible] with standard [illegible] demonstrating [illegible] temperatures of [illegible] providing thermal sensitivities of [illegible] 10°K and resolutions of 2 to 5 lp/mm have been [illegible]

b. Cooling Techniques

(1) Direct-Contact Coolers (Dewars). The simplest approach for cooling a detector is to mount the detector in an insulated receptacle into which coolant is poured from an external storage tank. In practice these devices are a bit more complicated than this because of the need to operate under varying conditions of gravity and acceleration. Several such mechanisms have been used and have provided cooling down to liquid nitrogen and helium temperatures. Utilization of direct-contact systems depends almost entirely on the amount of coolant that must be carried. Since the coolant must be replaced after each mission, the problem of logistics is difficult to solve in tactical operations.

SECRET

Table II-3. Performance of Elemental Detectors

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

[illegible]

[illegible] detectivity normalized to unit detector area [illegible] of the detectivities of IR-sensitive [illegible] made with the black body radiator at 500°K and [illegible]

Table II-4. Typical IR Image Tubes

Tube Type	Sensing Layer Type	Approximate Spectral Response (microns)	Operating Temperature (deg K)
IR Hybrid Tube	Bolometric	0.7 - [illegible]	300°K (ambient)
Thermicon	Bolometric	0.7 - 22	300 (ambient)
IR Camera Tube	Bolometric	[illegible]	300 (ambient)
IR Hybrid Tube	PbTe	[illegible]	77 - 110
IR Vidicon	PbTe	[illegible]	77 - 130
[illegible]	[illegible]	[illegible]	[illegible]

(2) [illegible] — [illegible] this type have been used [illegible] liquid-nitrogen temperatures [illegible] the coolant would be [illegible] used to obtain lower temperatures [illegible]

(3) Thermoelectric Cooling - Cooling devices based on the thermoelectric (Peltier) effect have been constructed, in which electrical energy is caused to flow through [illegible] the number of stages required to achieve cryogenic temperatures is impractically large. Using presently known and available materials, the practical utilization of Peltier cooling devices should be limited to the region around 200°K.

(4) Radiation Cooling - Detectors may be cooled by means of radiant exchange in a space environment due to the fact that the effective radiation temperatures of space is low enough to serve as an adequate heat sink for achieving the desired results by this means. It has been estimated that equilibrium temperatures of about 200°K can be achieved in this way. This limited capability is not applicable to aerospace systems.

(5) Solid Coolants - A type of cooling similar to the liquid direct-contact systems discussed above uses the sublimation of solids to produce cryogenic temperatures. The method operates by the maintenance of low pressures above the solid. It has been stated that for a 30-lb system weight, [illegible] of cooling for one year can be obtained using solid methane at 77°K as a coolant. A hydrogen system could sustain a similar heat load at [illegible]°K for a system weight of about [illegible] lb. Efforts to develop a 90°K methane system are currently being carried on. This technique has been of greatest interest in connection with space work, but so far has not been programmed for manned aerospace systems.

(6) Closed-Cycle Cryostats - Various closed-cycle cryostats have been tested. A low-capacity (0.5-w) cooling system involving several stages has achieved a temperature of 4.2°K. However, the present design does not have sufficient cooling capability for use on linear or mosaic detector arrays, where 1.5 to [illegible] w would be needed. Two other such devices have been built and successfully used for cooling single elements in airborne operation. These provide 26°K temperature in approximately ten minutes. One of these devices is being developed for the [illegible]

SECRET

c. Window Materials

The [illegible] IR [illegible] by Eastman Kodak Company (magnesium fluoride) and [illegible] discs, which can be obtained [illegible] appropriate for IR/UV applications [illegible].

1) Irtran-1 – Irtran 1 has satisfactory physical characteristics and will transmit wavelengths from 1 to 8.5 microns.

2) Irtran-2 – Although Irtran 2 will transmit from 1 to 14.5 microns, its melting point (800°C) is considerably lower than Irtran-1, and its hardness is less. Other physical characteristics are quite satisfactory.

3) Gallium Arsenide (GaAs) – [illegible] windows of crystalline gallium arsenide transmitting from 1 to 15 microns have been used. This material does not function satisfactorily as a window at temperatures above [illegible].

4) Other Materials – A number of [illegible] materials are suitable for instrumentation use where small diameter discs or curved surfaces [illegible] in a particular wavelength band are to be used. However, where large discs or domes are required, the list quickly narrows. The [illegible] listed above should be considered illustrative only since even the excellent Irtran 2 [illegible] cannot be obtained in large-size discs or domes. No materials are available for use as windows in operational high-speed aerospace environments for wavelengths beyond 15 microns.

d. IR Reconnaissance Subsystems

The Reconofax VI and the AN/UAS-5 are two IR reconnaissance subsystems that will meet tactical requirements to a limited extent. These systems have a resolution of about 2 to 3 mrad with a thermal resolution of about 0.5°C operating at a V/H of 1 to [illegible] rad/sec.

High-speed/low-altitude IR reconnaissance techniques exist which provide a resolution of 1.0 mrad with a thermal resolution of about 0.3°C over a field of view of 140 deg at a V/H of 1.0 rad/sec.

Very-high-altitude/low-speed IR reconnaissance techniques which provide an angular resolution of 0.5 mrad with a thermal resolution of about 0.3°C also are available. No suitable window material is available for

[illegible] systems operating [illegible] resolution [illegible] available [illegible] reconnaissance. [illegible]

c. Ultraviolet

Ultraviolet techniques for reconnaissance [illegible] The most promising application [illegible] of rockets and space vehicles in [illegible] by the ionosphere or ozone layer. [illegible] niques are applicable to UV imaging as well [illegible] scanning techniques. A possibility exists [illegible] in the atmosphere over short ranges [illegible] great. Detectors and techniques exist [illegible] quite efficient.

2. Trends

a. Detectors

Solid-state techniques should make possible [illegible] arrays of 200 sensitive elements/cm by 196[illegible] make mosaic arrays having 10,000 elements [illegible] available by 1970. Also, experimental [illegible] effects with superconducting materials [illegible] are likely to become available by 1968/1970.

The trend in IR image tubes is toward more [illegible] permit them to operate at higher temperatures. [illegible] temperatures will converge on about 130°K, where [illegible] may be employed. Similarly, the tube temperature environment [illegible] in the direction of ambient. Electrostatic [illegible] lighter-weight tubes which use less power and [illegible] borne use, and low noise amplification will be accomplished after the scanning electron beam has been reflected from the sensitive [illegible] current gains of from 1000 to 2000 will be achieved.

The capability of achieving detection of temperature differences as low as 0.3°C with a resolution of [illegible] lp/mm [illegible] should be achieved by 1975. This will include extension of the long-wavelength capability to peak [illegible] sensitivity at wavelengths of 12 to 13 microns.

b. Cooling

Compact reliable closed-cycle [illegible] with cooling temperatures of [illegible]°K should be [illegible] this period. Closed-cycle coolers with [illegible] temperatures of 4.2°K will probably not be available [illegible] before 1970.

c. Windows

Large diameter discs up to 15 in. dia and [illegible] 12 in. dia [illegible] for low- and high-altitude [illegible] and [illegible] transmission out to 20 microns could be available in the 1967/1968 time period.

d. Subsystems

State-of-the-art advances in detector [illegible] techniques, [illegible], and coolers will make possible significantly improved subsystems using single-element, linear arrays, image tubes, and mosaic detectors. Thermal sensitivities of 0.001°C to 0.002°C [illegible] resolution and at a low V/H ratio. [illegible] possible with a sacrifice in thermal sensitivity [illegible]. [illegible] possible subsystem resolution capability [illegible] shown in Figure II-9. This curve [illegible] resolution and a V/H of approximately [illegible] rad/sec. Subsystems could also incorporate tunable detectors and multi-[illegible] techniques, [illegible] multiple looks at the target providing additional target [illegible] data.

e. UV Techniques

Ultraviolet techniques will be advanced and probably will be applied to subsystems operating in space or over short [illegible] paths. UV electro-optical image tubes and photography seem to offer the best possibilities for [illegible]ploitation. UV optical components will be available for improved imaging and filtering. Lasers operating in the UV region are a distinct possibility.

3. Problems

Problem areas in IR/UV technology include:

1) Application of solid-state techniques to IR detectors to provide satisfactory linear arrays and mosaics.

2) Stable uniform photosensitive layers and effective cooling techniques for imaging tubes.

Figure II-9. Approximate Resolution Trend, Infrared Subsystems

3) Durable IR detectors.

4) Increased cooling capacity of [illegible] for IR detectors and [illegible].

5) Optical materials, [illegible] of [illegible] windows, and refractive lenses having long-wavelength transmission characteristics that are capable of withstanding environmental conditions.

6) Techniques for subsystem analysis and synthesis to optimize tradeoffs for desired IR subsystem performance.

7) Techniques for producing efficient high f/# capability.

c. Emphasis:

1. Exploratory Development:

1) Although a few of the sensitive elements are reaching theoretical limits of sensitivity, the point where the intensive search for better detectors can be abated has not been reached. Detector development should include attention to:

a) Small cells having desired wavelength sensitivities, low time constants, and near photo noise level in sizes of 0.1 x 0.1 mm or less.

b) Low-noise linear array detectors and mosaics having solid state preamplifiers built as an integral part of the sensitive element (back to back).

c) CW tuning and the magnetic effect on super conducting detectors at liquid-helium temperatures.

2) Window and lens materials compatible with reconnaissance environments must be developed in sizes up to at least 15 in. diameter. These materials must also have a wavelength transmission capability ranging between 1 to 20 microns in addition to other required physical characteristics such as capability to withstand intense heat or low temperature when in steady-state or shocked conditions.

3) Techniques for IR-augmented [illegible] should be developed as a means of [illegible] with [illegible] high V/H [illegible] capabilities.

Although work in the above areas is presently programmed, manpower on these programs should be increased by at least 25 percent, [illegible] to approximately $400,000.

b. Advanced Development

Emphasis should be given to developing complete IR subsystems that incorporate techniques resulting from the above exploratory development program as well as the advanced stabilization and image-motion compensation previously discussed in Sections III B and [illegible]. Particular emphasis should be given to development of the following IR subsystems and to integrating these subsystems with other reconnaissance subsystems and ancillary equipment:

1) A very-high-altitude IR subsystem to verify a [illegible] capability for IR reconnaissance from space and very-high-altitude aircraft. Although this subsystem would be flight tested in a high-altitude aircraft, it would incorporate techniques suitable for use in satellites. An angular resolution of [illegible] mrad and thermal resolution between 0.1° and 0.3°C is desired. Development cost would be on the order of [illegible].

2) A low-altitude IR subsystem to verify a capability for IR reconnaissance from low-altitude high-speed aircraft. This subsystem should have an angular resolution of at least 1 mrad, thermal resolution of 0.5°C and a V/H capability of at least 2 rad/sec. This capability should be forward looking with near-real-time (less than 0.1 sec) display. Fast-scan photo-tape, and linear-array or mosaic detectors could possibly be incorporated. The state-of-the-art will support such a development by FY 65. Development cost would be on the order of $900,000.

3) A program should be initiated to provide a compact reliable closed-cycle 5-w-capacity cooling system with capability to reach and maintain equilibrium temperatures of 25 to 30°K and of 4.2°K.

F. HIGH-RESOLUTION GROUND MAPPING RADARS

1. [illegible]

Present high-resolution [illegible] are based on a synthetic aperture concept. These require acquisition [illegible] of data samples on each target or scatterer. [illegible] must be obtained [illegible] distinguished from an adjacent target. [illegible] accomplished by a coherent [illegible] resolving of the phase history of the [illegible]. [illegible] relative range of the target [illegible] platform travels to the side of a target [illegible] constitute the desired history.

The sampling of the doppler history [illegible] which introduces other constraints. The pulse [illegible] low enough to permit return of a given [illegible] pulse before the [illegible] of a succeeding pulse. To restrict [illegible] present technology utilizes the [illegible] to restrict target illumination by the [illegible] targets which are acceptable. [illegible] which determine the swath width which can be [illegible].

Constraints similar to the foregoing [illegible] coordinates of the [illegible] are also imposed on the [illegible] coordinates [illegible]. In this case the [illegible] must be sufficiently high to [illegible] the target. [illegible] mines the beam width of the radiated pattern. [illegible] the terrain perpendicular to the velocity vector of the vehicle, the radiated energy must be restricted to [illegible] ities are sufficiently low. This implies that the highest doppler [illegible] of the signals received must be below that which can be [illegible] by the pulse repetition rate, and in effect means that the antenna must not move in space more than either one-half or one-quarter of the antenna length between pulses. Whether the one-half or one-quarter rule applies depends upon the radar system and the techniques employed in processing the information. In addition, design parameters must be chosen to give adequate latitude in other elements of the design.

a. High-Resolution Aircraft Radar [illegible]

Several high-resolution radars have been developed and flight tested in recent years. [illegible] radar, which has [illegible] the AN/APQ-[illegible] Mod 3 radar has been in flight test [illegible] more than a year. This radar utilizes [illegible] Processing to derive [illegible] Ranges on the order of 70 n mi [illegible] 100 ft have been obtained.

b. Airborne Moving Target Indicator (AMTI)

Existing airborne Air Force AMTI does not give target direction or speed for computation of the lead distance to the target, as is required for long ranges. Present technology can [illegible] functions.

An example of a gross overall [illegible] type of equipment is the forward-scanning AN/APS-27 as used in the [illegible]. This equipment is non-coherent and uses the FM cancellation technique. The detection capability is a truck or similar [illegible] moving at a minimum radial velocity of 4 knots at a range of 20 n mi. This equipment became operational in 1956.

A different type of equipment that also utilizes AMTI is the AN/APS-95 airborne early-warning long-range aircraft surveillance equipment used in the RC-121. This equipment is a [illegible] lock non-coherent receiver with an FM cancellation unit. This equipment is basically for detection and tracking of [illegible] aircraft [illegible]. It is the operational outgrowth of the Navy AN/[illegible] radar program and became operational in late 1960. The detection capability of the radar is a B-47 or similar target moving at a minimum radial speed of 25 knots at a 150-n mi range.

Another application of AMTI techniques is the MA-1 fire control system of the F-106 aircraft, which is a non-coherent forward-scanning interceptor-type of equipment using an FM cancellation unit that became operational in 1959. With a B-47 aircraft as a target the minimum detectible radial velocity is 4 knots at a maximum range of [illegible] n mi. The two basic limitations to this equipment are that it has AMTI capability only in the search mode and not in the track mode, which could cause loss of the target when going from search to tracking, and that it is effective only over a very narrow-view angle directly ahead of the aircraft.

An increase of [illegible] field surveillance [illegible] required for the army. [illegible] and Army testing [illegible] non-coherent and uses [illegible] moving at a minimum radial velocity of [illegible] n mi.

2. Trends

a. High-Resolution Ground Mapping ([illegible] Radars (Side Looking))

An estimate of present and future radar resolution is given in Figure II-10. The resolution and range indicated for present [illegible] have not been flight tested to date, but [illegible] fabricated and installation in aircraft is progressing.

The estimates for the 1965/1966 period are for experimental [illegible] that can be fabricated by that time. The performance is based on [illegible] aerodynamic vehicles, with effective apertures of [illegible] and a capability of mapping terrain [illegible] 2-in. grass. In this time period [illegible] data for display to an operator or for [illegible] able in approximately 25 sec or less. The swath width [illegible] imately 10 to 20 n mi.

In the 1967 time period feasibility of a radar with 20- to 50-ft ground resolution from a 150-n mi altitude [illegible] vehicle could be demonstrated. Swath width without multiplexing would be [illegible] 20 n mi. [illegible] ground processing of the signal would probably be required.

By approximately 1970 it is expected that 5- to 10-ft ground resolutions will have been proved feasible at ranges of 100 to 300 n mi. [illegible] aerodynamic vehicles obtained values of ranges over 100 n mi may be in doubt because of the shallow depression angle at which targets would be viewed and the resultant shadowing. At orbital altitudes the aspect angles are more favorable and larger antennas can be used. Although larger antennas are desirable to obtain the gain required for [illegible] they also can introduce an undesirable characteristic. To obtain fine resolutions in long synthetic arrays, it is necessary to accomplish focusing, but this can be accomplished only up to the point where the resolution is one-half of the real antenna length. This limit may be reduced by dividing the antenna aperture into smaller segments and then processing the signal. However, this technique has not been fully investigated nor has its feasibility been proved.

Figure II-10. High-Resolution Radar Technology Trends

All the above [illegible] posed by [illegible] [illegible]. [illegible] resolution limits of [illegible] [illegible] rate and required [illegible]. Further [illegible]

At shorter ranges finer resolutions [illegible] be expected. [illegible] lution of 5 to 10 ft may prove [illegible] at ranges of [illegible] finer resolutions of between [illegible] ranges may be [illegible] by 1970/1975.

b. Airborne Moving Target Indicator

The trend in AMTI is an increase in range capability [illegible] and capability to discriminate [illegible] targets moving at [illegible] knots by 1970.

5. Problems

The operational basis of radars employing synthetic aperture concepts is that the vehicle is flying along a straight line course or along a predictable path. In the case of the straight-line course the doppler follows a predictable function. However, where deviation from [illegible] is caused by vehicle instability, wind gusts, etc., a perturbation is [illegible] jected into the doppler history which, if not corrected, will [illegible] processing of the information to achieve the expected resolution. It has been the practice in the past to locate accelerometers on the antenna to sense this unwanted motion and to insert compensation into the radar [illegible] achieve the high resolutions required in [illegible] compensation probably will be necessary. Present technology is evolving around the use of high quality inertial platforms and accelerometers placed at or near the antenna to accomplish this function.

Positional accuracy of the data from the radar can be affected by several factors. For instance, when the vehicle is assumed to be traveling a straight path but the course deviates at a rate which is well below the build-up period (the time required to compose the doppler history) for the synthetic aperture, a relative azimuth shift [illegible] occur if compensation is not introduced. The percentage of azimuth shift as a function of range is approximately equal to the ratio of the uncor- rected velocity component normal to the assumed straight path and the velocity along the assumed straight path.

[illegible] operating in a [illegible] tional accuracy is [illegible]. The [illegible] velocity [illegible] assumed [illegible]

The correlator or processor used in high-resolution radars is one of the major problem areas. To employ high resolution [illegible] integrate the energy that is collected [illegible] the antenna beam into a spot which [illegible] collapsing ratios, extreme precision is required. [illegible] will necessitate new implementation techniques which will not only [illegible] the required precision but also will be capable of compensating for some of the uncertainties and errors introduced by other elements of the radar.

4. Emphasis

a. Exploratory Development

1) Change Detection - Recent advances in the resolution capabilities of airborne radar equipment have renewed interest in investigating the capabilities of radar sets to detect long-term changes on the ground. Much previous work has been done on map-matching techniques for guidance purposes. With this effort as a background, a new program has recently been initiated emphasizing the long-term moving-target detection capabilities that may be available in high-resolution radars. This program is to include laboratory and experimental investigation and analysis for radar signal correlation of change detection. However, the present program does not place enough emphasis in this area, which is considered to merit a prime development effort.

2) Special Processing - Present in-flight optical correlators are large and bulky. Development is required to exploit the potential of electronic and optical processors and of hybrid combinations of these techniques. The present program does not place adequate effort on this technology.

3) Side-Looking Radar - Further improvement of side-looking radars will require additional exploratory development in several problem areas. In connection with motion compensation, new approaches are required to ease the stringent requirements on inertial devices. Approaches to obtain auto-focusing of the synthetic array with perturbed flight paths could contribute

significantly to improving [illegible] to gaining increased performance. [illegible] must be [illegible] on a [illegible] locations.

4) Microwave Thermal Detection Sensors - The state of the art of microwave thermal sensors has been [illegible] and investigation of some of the [illegible] have been completed. Resolution has been limited to the angular beam width of the antenna pattern at the operating frequency, resulting in resolutions on the order of 1 deg. However, this type of sensor will not perform effectively unless improvements of many [illegible] are achieved. New concepts for implementation must be [illegible] conventional [illegible] limitations. Since these require a breakthrough, extensive studies and investigations will be necessary to realize further progress.

5) Foliage Penetration - Techniques involved in penetrating foliage should be investigated.

6) AMTI - The study of AMTI techniques should be expanded to provide capability to deal with the following conditions:

a) Aircraft speeds up to Mach 3.0.

b) Detection of ground vehicles moving as slowly as [illegible] knots.

c) Resolution of [illegible]-size targets.

d) Ranges to 100 n mi.

7) General - To obtain more design freedom, increase resolution, range, and swath width without use of multiplexing [illegible], new concepts for the overall radar are required. These imply a need for new technology for generating the microwave energy as well as for a means of obtaining it in usable form at high average power levels. When atmospheric propagation is found to limit resolution with present concepts of implementation, new and less restrictive approaches must be found. Although present concepts may not extract all the usable information in the electromagnetic waveform, depolarization at the target may contribute useful information.

(b) Funding - Present [illegible] approximately 20 percent, which is [illegible] over present expenditures. [illegible]

6. Advanced Development [illegible]

The 665A program includes development of optical and electronic [illegible] devices but does not include development of high-density storage devices to operate in conjunction with the correlators. The storage devices that should be considered are for short-time and for long-time storage of processed information.

The 665A development program should be extended beyond the present termination date. The results of exploratory development [illegible] new technology in charge detection, MTI, high-resolution [illegible], and processors, which will form a base for advanced development. Starting in 1965, funding should be increased by approximately 15 percent, which is equivalent to about $1,500,000 for the 1965/1967 time period.

c. Airborne Communications Intelligence (COMINT) System Elements

(1) Antennas - [illegible] in the airborne COMINT system may [illegible] the antennas normally used [illegible] are used [illegible] VHF/UHF [illegible] gain to about 12 db with [illegible]. Ordinary aircraft will use a wide variety of antennas [illegible] to extend frequency coverage but these will not be universally adopted until justified by changes in the signal environment or intelligence requirements.

(2) Receivers

(a) Sensitivity - In general, receiver sensitivity (minimum detectable signal) is not a serious problem. [illegible] limitations are more severe. Noise figures range from 4 db at VHF to 17 db at SHF. Sensitivity at SHF ranges from -79 to [illegible] dbm. In the case where the signal to be intercepted is directive (i.e., point to point), [illegible] could be usefully employed. In general, [illegible] if vigorously pursued can provide sensitivity to ground receivers.

(b) Bandwidths - Bandwidth requirements for present airborne communications receivers do not normally exceed 50 kc.

(c) Scanning/Tuning - Both continuous and digital mechanical and electronic scanning are utilized. State-of-the-art rates are as given previously (Ref. Section III F 1, a).

(3) Recorders - Standard 15-kc audio bandwidth recorders are used with additional channels provided for auxiliary digital data such as frequency, time, bearing, etc., and for operator comments. Wide-band width recorders (25 kc to 1 Mc) are available on a shared basis. Tape loops are used to provide a 10-sec delay while decisions regarding a particular intercepted signal are made.

(4) Displays - Activity rasters showing frequency and time of activity are controllable to display segments of the total spectrum of coverage. Total coverage is from 50 to 1500 Mc, and 0.1-, 10-, and 100-Mc segments may be displayed. Frequency and other necessary needed numeric data may use special neon (Nixie) tubes for display. When extensive remote control of equipment is utilized, special lighted control panels with pulsating operator-prompting lights are available.

c. Ground-Based [illegible] Sensors

(1) Antennas

(a) Gain [illegible]

VHF

4-Helix Array	[illegible] db ([illegible] Mc)
28-ft Parabolic Reflector	[illegible] db ([illegible] Mc)
Log-Periodic	[illegible] db ([illegible] Mc)

UHF

60-ft Parabolic Reflector	[illegible] db ([illegible] Mc)
Corner Reflector	[illegible] db ([illegible] Mc)

SHF

[illegible] 8-ft Parabolic Reflectors	[illegible] db ([illegible] Gc)
6-ft Parabolic Reflectors	35 db ([illegible] Gc)
Horn Reflector	20 db ([illegible]-18 Gc)

(b) Scanning/Tracking - Many ground-based [illegible] antennas are capable of 360-deg coverage. Positionable, [illegible], and [illegible] types are used. Search antennas often use sector [illegible] to increase probability of intercept. Present scan rates vary from [illegible] to [illegible]. Maximum tracking rates are only a few deg/sec, but this is satisfactory for present applications.

(c) Location Accuracy -

Below 50 Mc — [illegible] percent of range

Above 50 Mc — less than [illegible] percent of range

(2) Receivers - Crystal video, tuned radio frequency (TRF), and various superheterodyne types are being used and frequencies from [illegible] to 18 Gc are being covered. Below 1 Gc the ground-based [illegible] receiver sensitivities are generally limited by the ambient temperature within the view of the antenna lobe. Above 1 Gc front-end noise provides the limit upon the system noise figure. Present [illegible] receivers have noise figures in the 6- to 9-db range. Minimum detectable signals range from -144 to -174 dbw/m^2.

(3) Recorders - Video recording equipment [illegible] up to 4 Mc bandwidth are available. A 1-Mc recorder with 15 minutes [illegible] recording time per tape is more generally used. [illegible] ground-based ELINT consoles [illegible] magnetic tape [illegible] recording. Wideband [illegible] photographic recording of [illegible] in a shared photographic console.

(4) Displays - Displays include general purpose oscilloscopes, [illegible] azimuth rasters, amplitude-versus-frequency rasters, [illegible] type D/F indicators, and 5-inch oscilloscopes of the [illegible] variety for display of pulsed signals. Video switching is used to transfer signals to analysis consoles where these displays are presented and photographed.

d. Ground-Based COMINT Sensors

(1) Antennas - For target location it has been necessary to establish D/F networks and to provide the necessary antenna characteristics and communications support for this capability. [illegible] requirements for better D/F accuracy have had a pronounced influence upon the types and characteristics of the [illegible] antenna complex. Present azimuth accuracy is 1 deg at 50 Mc and less than 1 deg above this frequency.

(2) Gain

VLF/MF	
75-ft vertical wire	10- to 1000-kc negative gain
Loop	400- to 160-kc negative gain
HF	
2- to 30-Mc doublet, beverage, sloping-vee, rhombic, and large circularly-disposed antenna arrays (CDAA).	2-15 db
VHF	
Yagi, corner reflectors, CDAA.	5-12 db
UHF	
Same as VHF plus parabolic reflectors.	Up to 25 db (limited by dish size [illegible])
SHF	
Same as VHF.	Up to 30 db with presently used dishes.

(b) Scanning/Tracking - All scanning and tracking is manually con- [illegible] and, except for [illegible], [illegible] of a few [illegible]/sec are generally satisfactory for present [illegible] although [illegible] will be [illegible] in the general search [illegible]

(c) Receivers - With minor exceptions [illegible] all the equipments in the ground-based COMINT [illegible] conventional electron-tube design. Transistor [illegible] 1970. The great majority of the receivers are [illegible] single-channel narrow-bandwidth manually-tuned types. When multiple channels or wideband reception is required, modified standard receivers [illegible] combined and operated in parallel to provide required capacity. Panoramic and signal-seeking receiver types are also used for search and other special functions.

(a) Sensitivity - Receivers used for ground-based COMINT [illegible] are designed to operate within a few db of the ambient noise up to about 100 Mc and within a few db of the 1959/60 state-of-the-art at higher frequencies. At VHF, panoramic receiver noise figures average 10 db, and at SHF, 7 db. VLF noise figures are dominated by atmospheric noise.

(b) Scan Rates - Much of the present system utilizes manual tuning since recognition of the emitter is a time-consuming process at present. Although voltage-tuned magnetrons and [illegible] are available in selected bands from 200 Mc to 100 Gc, [illegible] microscan receivers can repetitively sweep a range of 4 Gc in 20 nanosec, and digitally-tuned receivers can be placed on frequency in less than 1 msec [illegible] frequencies up to 50 Mc. Such scanning rate performance could not be fully exploited without drastic changes in operational concepts.

(c) Bandwidths - Any communications signal bandwidth which is intentionally transmitted is susceptible to reception. Most signals are in low and medium bandwidths and are readily accommodated by the ground COMINT system. The bulk of present requirements are satisfied within audio bandwidths. Data systems do not exceed 20 kc. One special wideband reception system in the HF band looks simultaneously at a portion of the spectrum 840 kc wide.

(3) Recorders

(a) Types - Voice, data, and video magnetic tape recorders are available. Ink tape recorders for automatic morse, facsimile, and photographic recorders are also used.

(b) Bandwidth - Photographic and magnetic-tape recorders capable of recording 4-Mc bandwidths are available today.

(c) Recording Time – [illegible] continuous recording [illegible] are more useful and tape loops [illegible]

(d) Displays – [illegible] time displays, maps, charts, and [illegible] the tracking and identification of signals and targets, are used. [illegible] displays for supervisory and maintenance [illegible] are becoming more common.

2. Trends

a. General Technology Trends

Some important trends applicable to electronic technology in general, including component density, reliability, weight per function, etc., will be realizable only if integrated electronic techniques [illegible] time to be developed and utilized.

Figure II-11 shows the trend toward miniaturization which could occur by 1975 and is based on a 100-channel intercept receiver as a reference parameter. A 10-fold decrease in size is expected to be achieved in the 1965/1975 time period.

Weight trends are assuming greater importance even for ground-based equipments, particularly when man-pack or similar mobility is required. Figure II-12 shows that a 90-percent reduction in weight could be obtained by 1975.

Reliability in terms of mean-time-between-failures (MTBF) for an equipment containing 1000 active components is shown in Figure II-13. Such equipments could achieve nearly two orders of magnitude improvement in mean-time-failure by 1975 if the technology is applied.

b. Location Accuracy

Depending on platform characteristics, the uncertainty of emitter location for airborne systems will improve from 5 to [illegible] percent of range over the range from 2 Mc to 40 Gc. If great concessions are made in airborne platform characteristics toward satisfying electromagnetic reconnaissance objectives, this same accuracy might be extended downward into the HF band. Accuracies of 3 to 10 percent may be possible, even in the [illegible] HF bands.

Use of phase measurement is being investigated for airborne location-finding on a pulse-to-pulse basis. It shows promise of providing 1-deg accuracy in both azimuth and elevation. Simple [illegible] antenna structures cover approximately octave bands. A breadboard system covering S-band is being fabricated.

Figure II-11. Miniaturization Trends in Electronic Equipment

Figure II-12. Weight Trends in Electronic Equipment

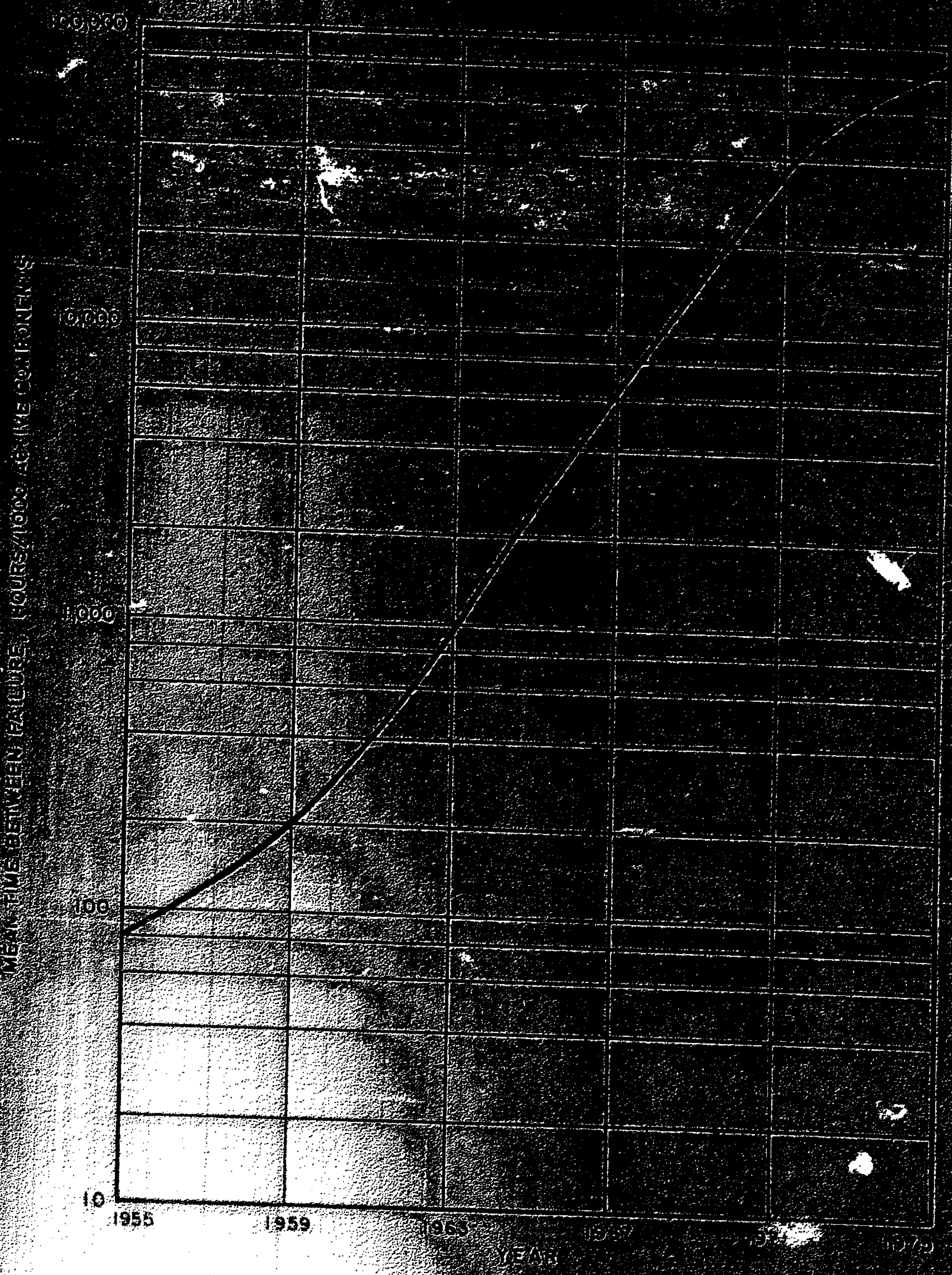


Figure II-13. Reliability Trends in Electronic Equipment

Within the 5- to 50-Mc frequency [illegible] systems. Better than [illegible] accuracies have been obtained using flush-mounted [illegible] antennas [illegible] horizontal and vertical polarization.

Passive tracking can be provided with airborne systems through application of techniques employing electronically-steered phased array antennas. One approach which has been demonstrated is the "reflectarray" antenna system which uses a diode semiconductor as a phase shifter. Several microwave diodes are mounted at discrete intervals inside short sections of wave guide. The proper diode is biased to give the phase necessary to simulate the desired contour of the reflector. Beam scanning is accomplished by activation of the proper diodes in the guide.

Large ground SIGINT stations will also obtain emitter location accuracies no greater than 1 percent of range and possibly an order of magnitude less than this. If radio-astronomy methods are adopted, [illegible] to 0.01 percent of range may also be obtained, although [illegible] in time and other signal information. However, mobile and transportable sites may have to rely upon correlation with other sensor outputs to reduce location uncertainties below 10 percent of range. For [illegible] mobile sites, the range is usually [illegible], and the absolute value of the uncertainty is consequently reduced to near [illegible] levels.

c. Antennas

Antennas at X-band scanning 360 deg at 200 rps have been experimentally demonstrated. Electronic scanning has been demonstrated at megacycle rates but has not found wide field application. Antennas which are required to track moving targets have manually or automatically activated mechanical or electronic lobe control.

Inflatable, tunnel, or plasma antenna techniques as well as highly directive active/passive reradiation devices may find application in attempts to provide improved emitter location accuracies, reduction in aperture, improved efficiency, etc., for all types of [illegible] electromagnetic sensor systems. In addition, adaptive techniques allowing the antenna to compensate for multipath reflections caused by the airframe appear feasible today.

d. Receivers

General trends in receiver weight, space, and reliability technology should be similar to those previously described for electronic technology in general. In some portions of the spectrum, pre-amplifier noise figures of less than 2 db can be achieved using cryogenic techniques.

[illegible] Recording

[illegible] oxide recording [illegible] to have reached [illegible] bandwidth capability [illegible] hard, special applications for [illegible] and medium-bandwidth signals [illegible] of [illegible] tape speeds, nonrotating heads can provide [illegible] capability. Using rotating heads and a magnetic [illegible] speed of 30 in./sec, [illegible] bandwidths may be possible.

Thermoplastic recording up to 10-Mc bandwidth is available in the laboratory, and rapid development to 50-Mc [illegible] is anticipated shortly. A capability of 15-min recording time [illegible] 30-db signal-to-noise ratio (S/N), and from 3- to 5-percent [illegible] distortion will be available in the immediate future.

Electron spin resonance may find use for direct recording of signal activity over a 1-Gc bandwidth. Present [illegible] frequency separation can be expected to be reduced to 1 Mc. Such techniques may provide the technology necessary to provide time/frequency records of signal activity over very wide bands.

As recording periods become shorter and discrete amplitude levels are reduced (i.e., toward binary), recording devices approach the characteristics of delay lines and magnetic core planes. Electrostatic storage has high-density storage capacity (10^6 to 10^8 bits/in.^{2}).

[illegible] Displays

The present trend is toward more automatic transfer of [illegible] displayed data to magnetic-tape recordings. An analog track is also provided for the interceptor analysis console so that the operator can enter relevant comments regarding any unusual circumstances associated with the signal or equipment. Solid-state technology promises to reduce the overall weight and volume of displays and associated control circuitry by a factor of 10 to 20 by 1970, and as much again by 197[illegible]. Large [illegible] color displays with self-contained storage/regeneration capability are [illegible] development or study. In one experiment, operator efficiency in discrimination between crowded signals was increased 100 to 200 percent by use of color display techniques. These are available and could be applied to intercept systems existing today.

2. Adaptive Systems Organization

With increase in computer [illegible] capability (speed, memory capacity), has come advances in programming [illegible] followed by machine-generated [illegible]. [illegible] are thus more complex and abstract. Continued development [illegible] could yield a machine which might be considered as able to "learn" in the human sense.

The intercept system could have the necessary capability and flexibility to cope with the 1970 electromagnetic environment. Techniques are now available which automatically provide such functions as:

1) Antenna beamwidth and receiver bandwidth control.

2) Centering of the receiver pass band on the received signal.

3) Skipping those portions of the band which are void of activity.

4) Instantaneous recognition of pulses belonging to a particular signal pulse train.

If these techniques are applied to the signal intercept data processing problem the required on-line capability can be realized.

3. Problems

Important problems relating to EM sensors include:

1) Extension of range coverage of present electromagnetic systems beyond line-of-sight.

2) Development of airborne capability for accurate, instantaneous geographical location.

3) Providing of larger capacity near-real-time capability to uniquely identify specific emitters.

4) Providing capability for passive airborne tracking of [illegible]-band telemetry to determine launch and re-entry trajectories of long-range missiles.

5) Electromagnetic subsystems frequency coverage extension below 1 kc and above 40 Gc.

6) Techniques for detection of [illegible] jamming signals to determine technical capability and vulnerability.

7) [illegible] 360 degrees [illegible]

8) Improved receiver local oscillator stability to preserve and measure higher-order variation in signal parameters.

9) Development of methods and equipment for measuring the horizontal and vertical radiation patterns and power of foreign transmitters.

10) Application of advanced techniques to [illegible] systems to increase quality of intercept while reducing the quantity of information which must be acquired, processed, extracted, and disseminated.

11) Interception and processing of non-intentional, [illegible], and incidental electromagnetic radiations from important military, scientific, and industrial complexes.

12) Application of microminiaturization techniques and devices to intercept subsystems without increasing cost or decreasing reliability.

13) Improved receiver linear dynamic range response from present 40-60 db range to 90-100 db.

14) Ultra-low-noise receiver development in frequency bands applicable to extended line-of-sight intercept.

15) Development of ground-intercept antenna techniques which minimize their detection by unfriendly forces.

16) Development of techniques for predetection recording at the radio frequencies.

4. Emphasis

a. Exploratory Development

1) Extended-Range Coverage (Beyond Line-of-Sight) - Investigation of various phenomena as means for obtaining extended-range

coverage for intercept of signals beyond [illegible] should be undertaken. Natural phenomena of interest would include creation of an artificial ionosphere [illegible] [illegible] phenomena such as cloud reflection and [illegible] Sporadic E-layers [illegible] layer, and field-aligned scatter [illegible]. Cost of increasing the present effort in these areas would be on the order of $900,000.

2) Rapid and Unique On-Line Identification - Application of adaptive techniques to the recognition problem should be vigorously pursued. It seems highly probable that recognition in the future will require more subtle criteria associated with the function or purpose of the radiating equipment used in the targets of interest. The portion of current technology that appears most promising for meeting this requirement is the area of adaptive techniques, variously referred to as machine learning techniques, pattern recognition, and adaptive programming techniques. However, unless this area is accelerated the need will exist long before the research reaches a point where substantial benefit can be obtained. Required additional effort will entail a cost increase on the order of $600,000 over the current program.

3) Extended Frequency Coverage - The frequency spectrum from 0.01 to 10^{17} cps should be investigated to determine the bands or parts thereof that would be most likely to be used and to derive the operational advantages that would be offered to the user in specific situations. Development of the necessary intercept techniques is indicated in order to cope with the areas most likely to be used. A 200- to 300-percent increase in effort over the present program will require additional funding on the order of $570,000.

4) Improved Location Accuracy - Synthetic and dispersed antenna systems will be required for better airborne and hardened/inconspicuous ground-based antenna systems. The feasibility of providing distortion-free receivers to extract information which may be of specific use in the transmitter-location problem (e.g., phase information), should be investigated. Such an

effort is estimated to entail costs on the order of $70,000 per year for approximately three years.

a) Airborne Platforms - Improvements [illegible] techniques [illegible] the small-aircraft target [illegible] frequency range from HF through the millimeter regions. For example, there is no present D/F capability from [illegible] Mc through approximately [illegible] Mc for aircraft such as the RU-[illegible]. Techniques should be [illegible] placed on [illegible] basis to miniaturize HF antennas ([illegible] Mc). The use of "HALL" (Hall effect) antennas [illegible] is suggested. New techniques are required above the 250-[illegible] region to improve direction-finding accuracy and to reduce system complexity. Adaptive techniques allowing the antenna system to compensate for [illegible] reflections caused by the airframe should be investigated and [illegible]. The use of plasma antennas [illegible] should be investigated for physical [illegible]. Although instantaneous geographic location [illegible] at low altitude is recognized as the most [illegible] objective within this program, it remains [illegible] to be realized from this work. It is estimated that these tasks will require a funding increase on the order of $70,000.

b) Ground Based System - Results of the airborne-platform investigation are equally applicable to ground systems, particularly to mobile operations. It is possible that certain of the techniques may [illegible]; for ground-system applications, the space and weight restrictions may be eased. Transmitter location accuracies below 1 Mc, especially in [illegible], [illegible], VLF, and ELF, also must be improved. Accuracies of between 1 and 2 percent of range are desired.

5) Laser Intercept - The problems facing electromagnetic sensor systems in this area must be organized and analyzed before prototype hardware requirements can be prepared. A combination of sensors and artificially introduced scattering mechanisms may be required. Photon-beam interactions may also provide non-interruptive non-detectable intercept capability from locations orthogonal to the laser beam. It is estimated that these efforts will entail costs on the order of $[illegible] during the first year after go-ahead and $[illegible] the second year.

6) Adaptive System Organization Techniques - Studies should be directed to [illegible] and higher utilization [illegible] the transmitting [illegible] functions. [illegible] is the ability to [illegible] system [illegible] upon [illegible] zation of system resources [illegible] formation for which [illegible] intelligence [illegible] will be extracted and that all [illegible] from the system will be immediately eliminated.

Concomitant with the above is the full exploitation of the opportunities for open-ended system design and system functional flexibility which [illegible] can offer. Truly modular and polymorphic systems capabilities may be [illegible] for the first time. However, if this investigation is carried on separately from the foregoing recommendation, full collaboration on all pertinent aspects must be incorporated into each project. This investigation will require a 200-percent increase over the present program, which is approximately equivalent to $350,000.

7) Radiation Intelligence - Studies are needed to determine the areas most likely to pay off in surveillance of unintentional radiations. From these studies, prototype hardware should be developed to exploit these radiations. All non-intentional, byproduct and incidental radiations from military, scientific, and industrial complexes should be considered. Costs of these studies will be on the order of $400,000.

8) Pattern and Power Management - The present effort in this area now in progress under Project 1028 should be continued. Since resolution of these problems is critical to development of penetration aids and tactics, the work on this program should continue to be funded at a rate which will assure that efficient utilization can be realized. The present funding rate is considered adequate.

9) Miniaturization - Microminiaturization and ultraminiaturization should be pursued as a high-payoff effort that is particularly applicable to receiving systems. An extensive program toward development of thin-film circuits and solid-state techniques as applied to intercept equipments will make the cost of these

techniques competitive and possibly [illegible] than the methods used at present. Consideration should be given to items such as thin-film [illegible] and [illegible]. Tentatively such a program will [illegible] on the order of $[illegible]5,000 for the first calendar year [illegible].

b. Advanced Development

1) Airborne On-Line Data Processing - Airborne data-processing techniques for on-line emitter identification, location, and/or characterization should be developed, and application of existing computers and computer programs for processing all electromagnetic sensor data should be investigated. It is envisioned that adaptive and other advanced programming techniques such as pattern recognition will be required to reduce redundancy and to identify emitters in cases where any or all commonly considered parameters vary randomly or over complex patterns.

General-purpose high-speed computers having sufficient flexibility to respond to changes in signal environment also are needed. Economy and small size as well as commonality between air and ground mobile versions should be especially emphasized. This capability is [illegible] with respect to [illegible] ferret-system and Project [illegible] requirements. Development will cost on the order of $3,500,000 spread over a three- to four-year period.

2) Improved Location - Extremely lightweight, [illegible], and appliqued antenna/lens/reflector systems are needed for the ground-based equipment. Airborne configurations require a passive tracking capability to accuracies less than 0.5 deg in both azimuth and elevation. Desired target velocity and acceleration information may be derived from doppler measurements. The frequency range of primary interest for this purpose is between 2000 and 3000 Mc. Approaches which may be feasible are phased arrays and monopulse, but an exhaustive study should be made of all possible antenna techniques. It is envisioned that gyro-stabilized antennas will be required. This program will cost on the order of $3,000,000 spread over three years.

3) Reception of 40 to 150 Mc - Development [illegible] and operational [illegible] to satisfy the [illegible] collection requirement from 40 to 150 Mc. This program will entail costs on the order of [illegible] spread out over three years.

4) Ground Detection and Analysis of Jamming Signals - A ground-system capability for precise measurement of parameters which reveal the technical capabilities, vulnerabilities, and stage of the art in Soviet-bloc electronic countermeasure jamming equipment should be provided. As a minimum, a capability to determine the gross parameters of the emissions (frequency versus time, power versus frequency) is required. This program will entail costs on the order of $1,000,000 for approximately three to four years.

5) Measurement of Higher Order Parameter Variations - The problem of determining the capabilities and limitations of emitters evidencing ultrastability in one or more parametric characteristics needs to be studied. As a result of such studies, capability to measure the necessary parameters characteristics to the accuracy required must be developed. This study program will entail costs on the order of $117,000 for the first calendar year from go-ahead.

6) Air-Droppable Transceivers - Development of extremely small and rugged concealable transceivers for airdrop or surreptitious emplacement is recommended. Both electromagnetic and pressure-wave transducers should be accommodated. This study will entail costs of the order of $50,000.

7) Extended Range - As soon as the results of investigations of extended-range techniques indicate areas of reasonable payoff in specific collection problem areas, development to provide immediate exploitation should be initiated. Costs will be of the order of $1,500,000 spread over three years.

8) Adaptive Techniques - Development and evaluation of adaptive techniques are needed to improve emitter location accuracy and to increase signal identification efficiency. Costs will be on the order of $750,000 spread out over three years.

C. DATA TRANSMISSION

1. [illegible]

a. Existing Capability

The existing capability for [illegible] communications is limited to a low-speed capability of 50 bits per sec (bps). Present major vehicular communications [illegible] HF line-of-sight voice and HF single-sideband voice for [illegible] command stations.

b. Development Programs Now in Progress

1) Telstar Tests - A military transportable satellite terminal is being tested using the Telstar satellites. The Air Force initiated this program under which satisfactory voice and teletype tests have been made. Data transmission rates of 30 to 40 kilobits/sec can be achieved.

2) LF - Experiments have been conducted for air/ground long-range communications using LF. Bit rates of 50 bps or less are envisioned.

3) Wideband - Ground link tests have been authorized to provide a capability for transmission of photographic information from a satellite or an aircraft to ground. A [illegible] surveillance system developed by the Army Signal Corps has a capability of transmitting 5 Mc of video data, and a high-resolution digital TV developed by the Navy [illegible] video data at a 40-megabit rate. [illegible] encryption device for this link has also been developed. Broadband feasibility demonstrations and programs now underway include:

a) A wideband RF link breadboard operating at a frequency of 10.4 Gc has been developed for the Air Force and tested over a 30-mi path for a period of two months. This link has a capability of transmitting [illegible] megabits of data in an RF bandwidth of about [illegible] Mc and of transmitting 100 Mc video in a bandwidth of [illegible] Mc by wideband FM. Test results on this link showed excellent fidelity in the FM mode and few or no errors in the digital mode during the two months of operation. No difficulty was experienced with propagation anomalies, although it is recognized that two months is a small statistical sample when dealing with

atmospheric propagation. A program is underway with the National Bureau of Standards to [illegible] the degree of propagation degradation of [illegible] wideband links [illegible] through, [illegible] and [illegible].

b) An analog-to-digital converter to convert 25 Mc bandwidths at a 300-megabit/sec rate is undergoing preliminary design [illegible] at the present time. This system will handle 32 gray levels (5-bit precision).

c) An electrostatic photo-tape camera and readout device has been developed which is capable of [illegible] lp/mm resolution and electronic readout of 25 Mc video (see Section II.[illegible]). This development is attractive for data transmission because the image is stored directly by electrostatic charges on a tape and can be read out by an electron beam without any necessity of developing film.

d) An investigation of wideband multiplexing techniques to send four 25-Mc video signals over one 100-Mc channel is underway. Successful completion of this program would provide full utilization of the 100-bit link described above, which has four times more capacity than that required to transmit the highest bandwidth (25-Mc) video signal available today.

e) An EHF communication system is presently under development, including transmitter, receiver, modulation/demodulation equipment, and flush-mounted phased-array antennas. Design goals are 5 W of transmitter power at 50 Gc and an information bandwidth transmission capability of 100 Mc. Search acquisition and tracking problems with directive antennas in an air-to-ground environment will be investigated in this program.

4) Moon Bounce and Orbiting Dipoles - Study for development of an airborne terminal with a 10-kw X-band transmitter, 30-ft parabolic antenna, antenna-pointing computer, and maser receiver is in progress. This should provide a terminal that is compatible with use of West Ford dipoles and the moon, which would provide a long-haul air-to-ground link at low transmission rates of 50 bps or less. This terminal would be usable without modification for active satellites, providing the active satellite system frequencies were compatible with the West Ford frequencies. The information rate of such a system could be 10 megabits/sec.

5) Unmanned Satellite [illegible] (6.16) [illegible]

6) Secure Voice [illegible] will provide a secure [illegible] communications capability for the [illegible] secure voice system will be [illegible] system will provide a 100-wpm [illegible] voice capability.

7) 483L ACRP Secure Communication System - The [illegible] reconnaissance [illegible] system [illegible] 100 wpm will be installed in 21 ACRP aircraft and 35 [illegible] reconnaissance aircraft.

2. Trends

The near-real-time emphasis being placed on the reconnaissance mission for transmission of photographic and other information will require transmission of larger amounts of information over greater distances, both through space and around the surface of the earth. Table II-5 is a projection of wideband transmission based on [illegible] ground and aircraft coupled with the inherent problems of [illegible] problems. This table presupposes the needs for such operating modes will merit funding.

3. Problems

a. Wideband Data Transmission

1) Propagation Media - The limitations set by the propagation media may require multiplexing of the sensor output.

2) Synchronization - The high data rates place stringent requirements on data-transmission timing synchronization. Further problems are line and frame synchronization. At some point in the system timing accuracies of one nanosecond will be required.

3) Aircraft Antenna Design - Transmission of wideband data from an aircraft requires a tracking capability to line-of-sight stations or satellites. Acquisition of track between an aircraft antenna and a ground antenna is difficult, but a solution to this problem is anticipated in the near future.

Table II-5. Wideband Transmission Trends

Type of Operation	1970/1975 Capacity with Jamming as Described*	1970/1975 Capacity with No Jamming
One-way, aircraft to synchronous satellite to ground Aircraft .... 1 kw, 1 ft Dish Satellite earth coverage antenna .... 100 w, 10 db noise figure Ground station .... 60 ft Dish System temperature .... 300°K	7 to 15 bps, 60-db AJ protection with jamming from Haystack-type station	2-4 Mb/sec, 10-db S/N
Same as above, except satellite at 200-n mi altitude	600-3000 bps, 30 db AJ protection, depending on type of jamming and geography	50-100 kb/sec [illegible] 10-db S/N
Transmission of sensor information from satellite to ground station. Satellite .... 5 w Orbital Altitude .... 200-500 n mi Ground Station .... 60-ft Dish, 300°K	Does not apply unless jamming done from another satellite or an aircraft	100 kb/sec [illegible] 15-db S/N
Meteor burst or orbital dipoles Aircraft Power .... 10 kw, 18-in Dish Ground Station .... 60-ft Dish, 300°K	10-50 bps may be achieved [illegible] of jamming	50 bps [illegible]
Air to ground line-of-sight transmission	600 bps, 10-30 [illegible]	10 kb/sec [illegible]

*Ref. FORECAST Communications Panel Report

4) ECM - Present [illegible] transmission systems [illegible] operate in a jamming environment [illegible] operator intervention. It does not appear likely [illegible] capability [illegible] jamming [illegible].

5) Air-to-ground [illegible] relay by [illegible] would be vulnerable to jamming.

b. Secure Voice Communications

Secure voice communications requires a minimum bit rate of 2400 to 5000 bps. Transmission of these bit rates over long distances using HF will not be reliable because intersymbol interference caused by multipath will limit HF transmission rates. Intersymbol interference is produced when signal waveforms used to describe a particular bit interfere with those describing adjacent bit(s). Some form of satellite relay may be applicable. A tracking antenna would be required on an aircraft for relay via a satellite.

c. Operational Incompatibility

In many operations interference caused by friendly emitters can degrade communications. A multi-sensor aircraft will require a complete interference and radiation analysis, including data processors, radars, communications, navaids, etc.

d. Electro-Optical Converter

Electro-optical converters to utilize the wideband transmission systems now being tested are not available.

e. Antenna Stabilization

Antenna or antenna-pattern stabilization will be required for wideband air-to-ground data links.

f. Cryptographic Security

Cryptographic security for air-to-ground missions requires large heavy equipment. Subminiaturization techniques need to be investigated. Synchronization techniques are time-consuming and difficult to accomplish in a jamming environment. New synchronization and authentication techniques should be studied and developed.

5. Manual Versus Automatic

One of the most critical areas affecting information rates is the trade-off of man/machine [illegible] will be expected to resolve this dilemma.

b. Air-to-Ground [illegible] Transmission

(1) Information Transmission - The transmission of [illegible] information from an aircraft [illegible] is generally less attractive than for the satellite case because of the fact that the aircraft is in line of sight for relatively short time intervals and therefore requires advanced anti-jam concepts. Also, this type of [illegible] transmission has limited application, in that any attempt to provide aircraft, satellite, or balloon relays for [illegible] transmission beyond the horizon will leave the relay wide open to jamming.

In view of the anti-jamming (AJ) problem noted above, it would be worthwhile to perform some limited on board processing which would permit use of voice or digital data at rates of [illegible] bps [illegible]. For the near future it appears that [illegible] may give useful information. The photo or radar [illegible] the reduction of critical photos would require special training for working under stresses of battle conditions. If the [illegible] circumstances were not amenable with present concepts, the next alternative would be to provide an on-board digital or analog processor which could perform backup support for an operator. This would require the processor to be able to store radar and photo information of many targets in bomb damage assessment applications. With a flexible targeting scheme the storage could become unwieldy.

The number of photographic picture elements/in.^{2} at a resolution of 1 lp/mm can be determined by

$$Q = \left[\frac{2}{mm} \times \frac{25.4\,mm}{1\,in.}\right]^2 = 2580 \text{ picture elements (in.}^2\text{)}$$

It should be noted that for transmission of pictorial data it is necessary to scan each picture element approximately twice. General formulas and defintions applicable to information transmission are:

A Area (in.^{2})

R Limiting resolution (lp/mm)

SECRET

k = Scanning factor = (0.7)

n = Number of scanning elements required per $(mm)^2$ (62)

G = Number of gray shades [illegible]

n = Number of bits required [illegible] (63)

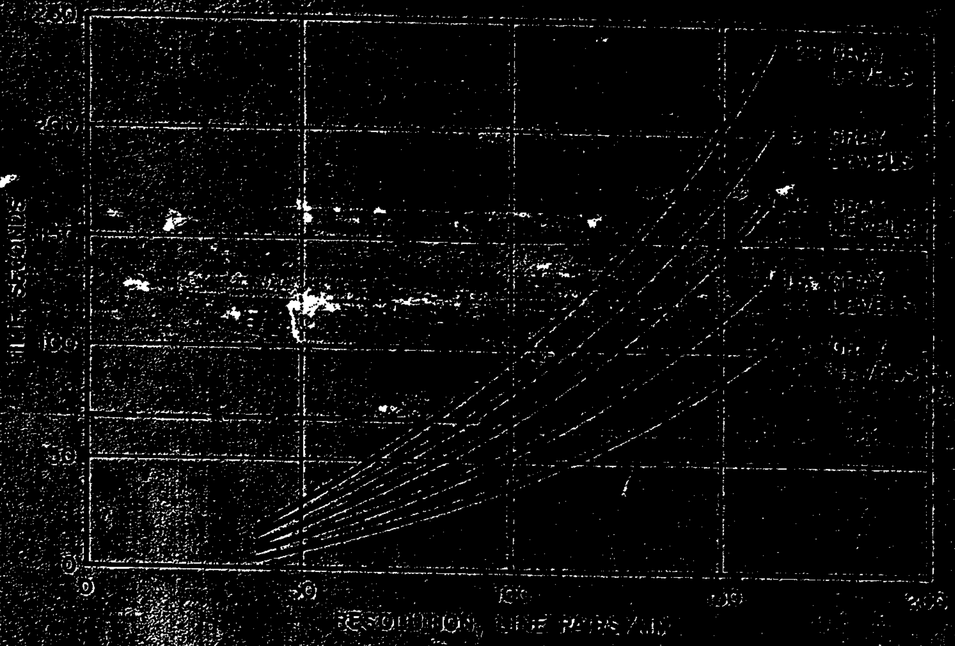
Techniques are being investigated to reduce the number of bits by using redundancy or by coding in combination with random key generators.

(2) Transmission Time - Before digital and analog transmission time can be compared it is necessary to normalize the digital signalling rate to equivalent video information bandwidth. Using the above assumptions, a 100-Mc video signal encoded into binary digital form using pulse code modulation (PCM) for 32 gray levels will result in a 2000-megabit signalling rate. Based on this equivalency, the transmission time for the analog or the digital mode is equal. However, the present [illegible] for encoding can provide only a 3000-megabit signalling rate, which is equivalent to a 12.5-Mc video bandwidth under the above assumptions.

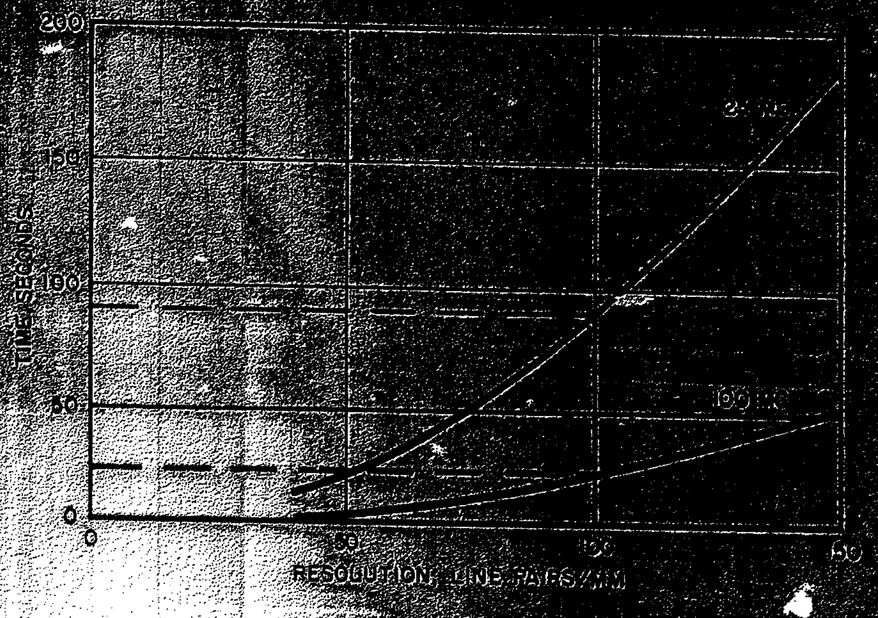
Figure II-14(a) shows the time required to transmit one 9- x 9-in. photograph at a 300-megabit/sec signalling rate. These curves are derived from Equation (63). As a typical example, the time required to transmit 32 gray levels at 40-lp/mm and 100-lp/mm resolutions is 11 and 70 sec respectively.

Figure II-14(b) shows the time required for analog transmission of one 9- x 9-in. photograph at a baseband video of 25 Mc/sec and at 100 Mc/sec. A typical example shows that for a resolution of 100 lp/mm, [illegible] and 21 sec are required for 25 and 100 Mc respectively.

Digital transmission requires a complex encoder that introduces another aperture with attendant degradation into the system, which is a major disadvantage. A second disadvantage is the extremely wide RF transmission bandwidth required. Analog transmission in the form of wideband FM (WBFM) is recommended, which affords operation at a lower carrier/noise ratio at a modest increase in RF bandwidth. For example, the 2000-megabit signalling rate requires a 3000-Mc RF bandwidth, while the equivalent 100-Mc video using WBFM transmission requires approximately [illegible] Mc. The receiving signal threshold is approximately equivalent for both modes. The present advantages of digital transmission are that true video encryption can now be accomplished only with a digital pulse stream and that digital transmission is preferred when regeneration of signals is desired for a large number of relays.



(a) Digital Transmission



(b) Analog Transmission

Figure II-14. Time Required to Transmit One 9- x 9-In. Frame at a Transmission Rate of 100 Megabits/Sec

4. Emphasis

a. Exploratory Development

1) Real-Time Air-to-Ground Narrowband Communications - Development of long-range air-to-ground narrowband communications is considered to be of prime importance. The areas which should be investigated include use of orbiting dipoles and the moon as reflectors for duplex communications, HF ground-wave communications from ground to air, and antennas or orbital relays capable of duplex operation with [illegible] protection. Narrowband communications are defined in this sense to include data rates from 50 to 5000 bps. Development of multi-user techniques, presently referred to as random-access systems, is considered to be essential for relay operations.

2) Line-of-Sight Wideband Transmission - More emphasis is required in the present program to provide antenna tracking capabilities. Although present propagation tests are considered sufficient for the air-to-ground links, a test package should be implemented to permit study of the effects of propagation on space-to-ground wideband signals. This package should be designed to ride "piggy-back" with a future orbital vehicle. Increased emphasis should be placed on development of techniques to reduce the number of bits that are required to transmit radar or photographic information.

An orbital reconnaissance vehicle will require a secure command and control network for readout of satellite sensor information. Emphasis for exploratory development in this area should be aimed at increasing the reliability of components in a space environment. The long term problem of maintaining secure command and control is under investigation in other programs.

For COIN or limited-war applications, techniques should be investigated to provide light-weight tracking antennas, receivers, and data-processing equipment for the wideband systems.

A 50-percent increase in the funding of exploratory developments relating to data transmission will be needed during the 1965/1968 time period. This will be equivalent to approximately [illegible]800,000 per year.

[illegible] Advanced Development

1) Narrowband A/G Communications - [illegible] program to provide improved [illegible] capability [illegible] range of from 200 to 300 [illegible] on the order of $1,[illegible] over the FY [illegible] time period.

2) Satellite-to-Ground [illegible] - [illegible] development of a 100-Mc baseband satellite-to-ground [illegible] should be attacked in a 2-phase program. The first phase should provide a 20-Mc baseband transmission capability. This program should be initiated in 1965 and be completed in 1970. Both analog and digital modes of transmission should be investigated to provide [illegible] system capability and a solid basis for [illegible]. The funding for this effort would be on the order of $[illegible] per year for the FY 65/FY 70 time period. The program should be carried on in the light of operating experience gained during Phase I to provide the highest data rates consistent with the state-of-the-art in encoders, modulation techniques, multiplexers, antennas, and power amplifiers. The goal should be an at least 100-Mc baseband. Funding would be on the order of $1,000,000 per year for the FY 71/FY 75 time period.

3) Aircraft-to-Ground Wideband Line-of-Sight Links - Techniques developed in the satellite case would be applicable to this program, which similarly should be divided into two separate phases. Funding would be on the order of $[illegible] per year for the FY 65/FY 75 time period.

4) Security - The advent of high-speed encoders, decoders, and processors will increase the problems of interference and radiation. Advanced development is required to provide overall system security. Applicable funding is included in foregoing items 2) and 3).

[illegible] DATA PROCESSING

1. State-of-the-Art

a. Photo Reproduction Materials

Except for the use of diazo-type materials for limited special-purpose applications, current all-purpose photo reproduction capability must be provided by gelatin silver-halide emulsions. Typical reproduction materials are Eastman Kodak [illegible], [illegible], and [illegible]. These materials are blue/ultraviolet sensitive and characteristically slow speed. Respective low-contrast resolution capabilities are 90, 180, and 300 lp/mm.

Except for very limited special applications, no unconventional material has all the necessary characteristics to warrant its replacing the reliable silver halides. Current capabilities of these unconventional materials are listed in Table II-6.

b. High-Quality Photo Reproduction

The conventional reproduction cycle is a four-step process involving generation of the original negative, the master positive, the duplicate negative, and the duplicate positive. Reference to quality in connection with discussion of reproduction technology always relates to the quality of the release positive.

In a precisely controlled laboratory environment 150- to 200-lp/mm low-contrast imagery can be reproduced with negligible loss of information content. In gelatin silver-halide systems this is accomplished by reducing the information density (enlarging the imagery) during production of the master positive. Systems using diazo materials can maintain this order of quality through continuous contact printing operations. However, the machines are extremely bulky, contain very high-energy high-pressure mercury-arc light sources, and require overly-sophisticated methods of cooling the lamps and collimating the light.

c. Photo-Processing in an Austere Environment

This type of processing capability is typified by the ES-39 portable photo laboratory to support OSR-405. This laboratory provides a highly mobile photographic capability designed for rapid deployment to world-wide locations. The laboratory will process 16-mm through 9.5-in. wide materials, contact print 5- to 9.5-in. materials, and enlarge 70-mm and 5-in. material two times (2X). The laboratory is capable of processing

SECRET

Table II-6. Reconnaissance Reproduction Materials

Material	Sensitivity (Exposure Index)	Resolving Power 2:1 Contrast (lp/mm)	Processing	Continuous Tone	Variable Contrast	Available
Gelatin AgBr	Blue/UV (10^{-2} to 10)	100-250	Wet	Excellent	Yes	Now
Vacuum-Evaporated AgBr	Blue/UV (10^{-4} to 10)	500	Simple Solution	Excellent	Yes	1966/1970
Diazo	Blue/UV (10^{-5} to 10^{-7})	800-1500	NH_3	Good	No	1966/1970
Kalvar	Blue/UV (10^{-5})	100-200	Heat	Poor	No	[illegible]
Free-Radical Dye	Red/Green (10^{-5})	800-1000	Heat Fix	Good	No	1967/1970

SECRET

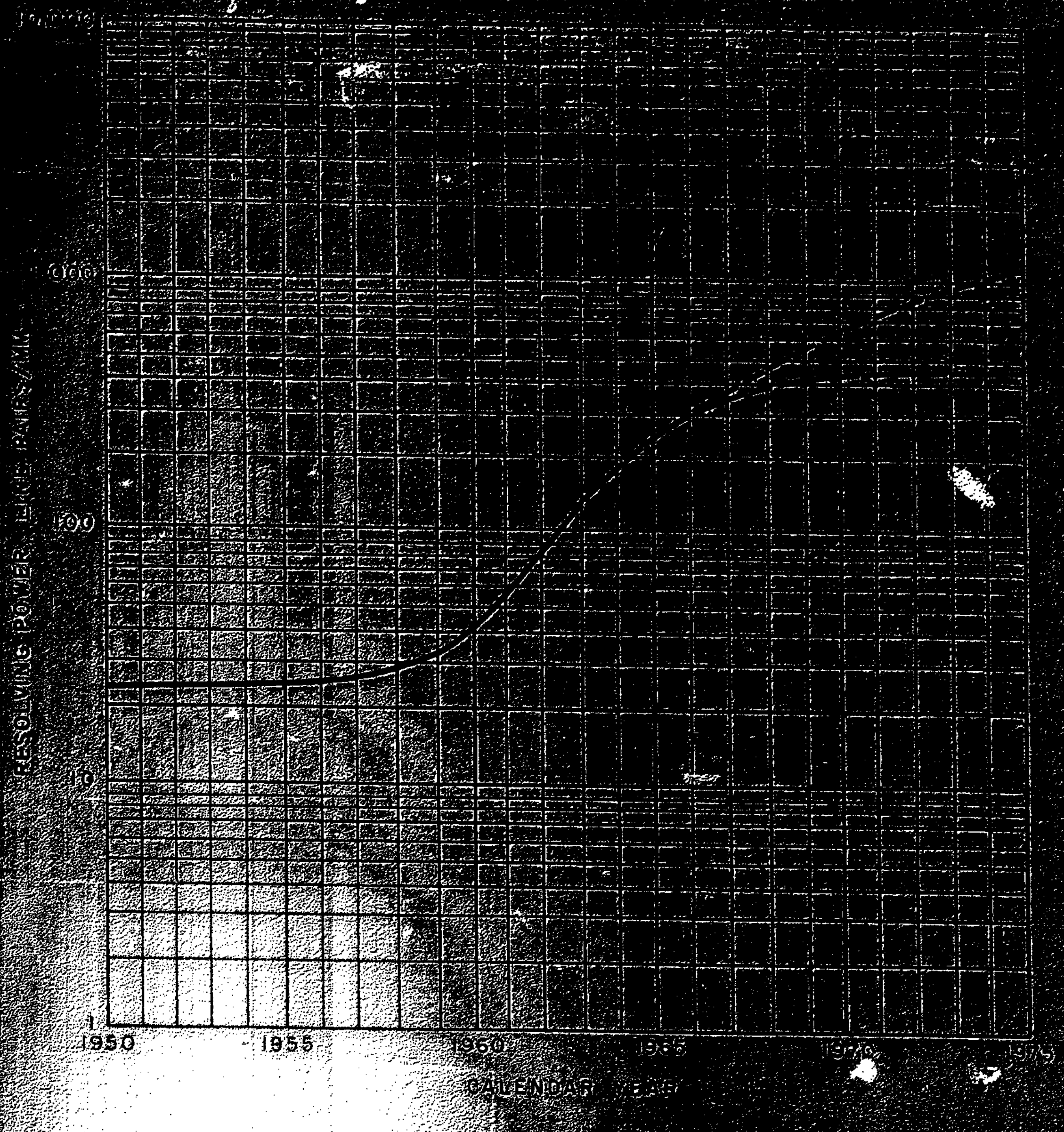


Figure II-15. Approximate Low-Contrast Resolution Trend for Reproduction Throughout Generations of Continuous-Tone Negatives

c. Processing in an Austere Environment

By the 1970/1975 time period techniques and [illegible] will be available [illegible] quality of the [illegible] comparable to [illegible].

d. In-Flight Processing

During the 1965/1970 time period diffusion transfer techniques [illegible] by aerospacecraft equipment will permit interpretation or ejection of a positive and retention of a high-quality negative. Improved monobath webs and developer-imbibed emulsions will permit near-real-time (1 to 2 sec from exposure) viewing of the negative. In the latter part of the 1970/1975 time period unconventional materials will be available to form visible images immediately upon exposure to actinic light. This will provide a real-time viewing capability and eliminate need for in-flight chemical processing.

e. Electronic Signal Image Recording

Electronic image recording or reconstruction can be subdivided into the elements of source of energy to which the recording material is sensitive, electrically controlled modulating devices for this energy, scanning devices, media which are sensitive to this energy, and media processing. Requirements are for increased recording bandwidth, immediate access to data, improved image quality, and simple techniques. Advanced approaches include electron beams, high-power light sources (lasers, plasmas, arcs), electrical probes or heads, light-interference techniques, and various electromechanical and electro-optical transducers. Media include thermoplastic deformation materials, both conventional and unconventional photo materials, and materials that are sensitive to electrical and magnetic heads and probes. The trend pertaining to recording bandwidth is shown in Figure II-16.

f. Special Photo-Processing Techniques

During the 1970/1975 time period, spectral zonal filtration data processing, grain integration, and contrast modulation techniques offer promise of much more discernible information for data extraction than existing techniques. Quality improvements of one order of magnitude can be expected from these techniques by 1975. By 1970 color and CD film will have been improved in speed resolution and simplicity of processing so there it will be a much more useful tool, although it will not replace black and white photography.

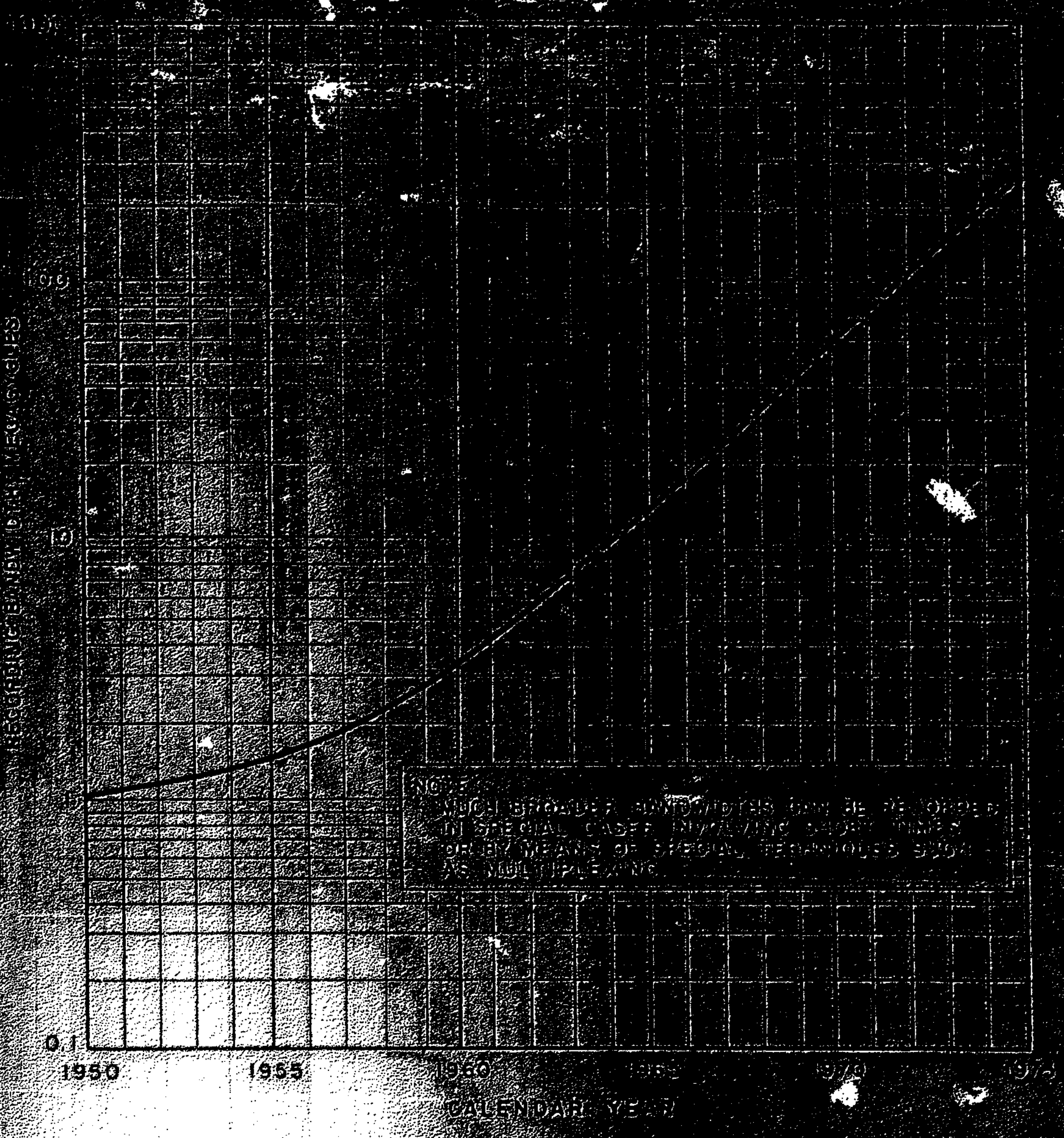


Figure II-16. Approximate Electronic-Signal Bandwidth Recording Trend for Reconstructing Scanned Images

3. Image-Data Processing (Electronic and Optical)

By the 1970-1975 time period, electronic and optical image-data processing will have been improved and [illegible] for many purposes. However, complete automatic target recognition and identification [illegible] not considered likely. Both optical and electronic image-enhancement techniques will be developed to a point where many degrading effects such as [illegible], atmospheric turbulence, aberrations, etc. can be greatly reduced. This will result in some increase in noise (grain), which in turn can be reduced by [illegible] integration techniques. Spatial filtering techniques will also become practical for many applications. Photographic and [illegible] bandwidth are expected to increase to approximately [illegible] respectively.

3. Problems

a. Photographic Reproduction Materials

Controlling gamma at unity or less, reducing size of grain structure, and producing homogeneous grain sizes are the main problems to be solved in making high-quality silver halide reproduction materials. The major problems to be solved in unconventional materials such as diazos and free-radical-activated dyes are to increase their density range, provide a variable gamma around unity, improve uniformity of density, increase sensitivity, and improve stability of the photograph.

b. High-Acuity Reproduction

Precision lenses and reproduction equipment operating in an extremely clean environment and having tight tolerances on humidity and temperature will be required. Increased speed of operation and completely automated computer-controlled reproduction operations are other areas that need investigation. More exact sensitometric techniques to provide the criteria for complete automation and for better control of unconventional materials during the reproduction cycle must be developed, as well as extremely high-energy light sources tailored to the spectral sensitivity of the relatively insensitive unconventional materials.

c. Processing in Austere Environment

The major problems in this area are:

1) Providing simple, portable equipment for controlling the processing environment.

2) Providing miniaturization that will permit [illegible] down to any including [illegible] processing capability.

3) Eliminating [illegible] image quality [illegible] of [illegible].

d. In-flight Processing [illegible]

The main problems in this area are:

1) Providing near-real-time visible images for in-flight interpretation or data transmission.

2) Simplifying and miniaturizing the processing apparatus and techniques.

3) Providing a rapid rate of processing while maintaining quality of processing. Quality must be comparable to that provided by conventional ground-based machine processing.

4) Providing a high-quality dry positive that can be ejected or that will be immediately available for interpretation when the vehicle lands. Quality must be equal to the first-generation positive produced by conventional printing techniques. Quality of the recoverable negative must not be degraded by the technique used to provide the positive. No post-development processing should be required.

e. Electronic Signal Image Recording

The major problems in this area are:

1) Providing energy sources and techniques which can be focused to very small points and which are suitable for modulating, scanning, and energizing media.

2) Providing electron-beam and light-source modulation techniques (0 to 100 percent modulation).

3) Providing electron beams of micron sizes and [illegible] intensities which can be modulated and deflected from 5 to 10 in. without loss of focus.

4) Providing techniques to permit electron image-sensitive media to remain outside the vacuum environment.

5) Providing modulation and scanning techniques for multiple channel or mosaic recording.

6) Providing [illegible] compatible with recording techniques. These media must be [illegible] processed, high-resolution, and have [illegible] and image-stability characteristics. [illegible] recording [illegible] including electron sensitivity, information quality, etc, may be obtained for these recording materials.

2. Special Processing Techniques

Problems requiring resolution are:

1) Understanding and controlling the effects of filtering on film contrast for effective application of spectral zonal photography. Simple quality control of color and IR film processing are also needed.

2) Investigating superimposition and registration problems with respect to noise integration.

3. Image Data Processing

Applicable problem areas are:

1) Two-dimensional computer programs and optical techniques to permit restoration of photographic images which have image smear and geometric distortion, and methods for volume processing of smeared and distorted images must be developed.

2) Computers must be greatly miniaturized and specialized.

4. Emphasis

a. Exploratory Development

1) Reproduction Materials - The current rate of effort on reproduction materials is considered to be adequate and no shift in emphasis is recommended. No significant additional improvements in advancement of the state-of-the-art could be expected by major increases in funding resources.

2) High-Acuity Reproduction - The current rate of effort on high-acuity reproduction for basic laboratory facilities is considered to be adequate. No shift in emphasis is recommended.

3) Processing in an Adverse Environment - Emphasis should be placed on dry-process techniques, [illegible] processes, and developer-incorporated emulsions [illegible] requirements. Some emphasis should be placed on new and more efficient reducing agents ([illegible]) [illegible] and help miniaturize equipment. Some effort should be expended on development of simpler processing techniques for the processing of color films. No such effort is currently in progress.

4) In-Flight Processing - Increased emphasis should be placed on solving the problem of providing [illegible], short cycle time processing, and high-quality processing at high rates. Dry-processing techniques, diffusion transfer techniques, [illegible] research and developer-incorporated emulsion research should be considered.

5) Electronic Signal Image Recording - Progress on both materials and techniques is required. Increasing sensor and data transmission bandwidths, requirements for rapid data access, and requirements for much better image quality or recording density, make the conventional CRT inadequate. Several promising new approaches are not being pursued. Multiple approaches should be investigated inasmuch as no single technique or medium is expected to fulfill requirements for all applications.

6) Special Processing Techniques - Recent preliminary research work on restoration of photographic images has been highly promising. Additional support should be made available to improve these techniques and to develop methods for volume processing of computer signals.

Although work in the above areas is presently programmed, funds and manpower on these programs should be increased by 25 percent, which is equivalent to approximately $750,000.

b. Advanced Development

1) Reproduction Materials - Introduction of new types of reception materials will cause major problems in manufacturing technology. A major government or commercial effort will be required to

convert the proven laboratory technology to the mass production capability required by systems applications. The possibility of commercial application of these materials may [illegible] commercial manufacturers to [illegible]. For instance, a commercial firm is currently [illegible]. Government cost would be on the order of $2,000,000.

2) High-Acuity Reproduction - Emphasis should be placed on computer-controlled automation of the processing and reproduction of extremely high-quality imagery. Methods of completely eliminating the human being from the clean room environment and of developing reproduction subsystems using [illegible] type materials to permit effecting orderly conversion to the use of these materials within the next five years should be emphasized. Cost will be on the order of $3,000,000.

3) Portable High-Resolution TAC Reconnaissance Photo Reproduction Laboratories - Special TAC reconnaissance, COIN, and limited war missions utilize high-resolution cameras that require sophisticated handling of film during processing. Present effort on OSR-105 provides a portable photographic capability for normal TAC missions. A facility with the same mobility but with high-resolution capability needs to be developed. Cost would be on the order of $2,000,000.

4) Processing in an Austere Environment - Development of miniaturized processing equipment that will ease portability problems and permit hand portage should be emphasized. A high-acuity mobile processing capability for special applications and continuous-processing equipment for color films to support low-altitude reconnaissance are required. Particular attention should be given to developing equipment that uses dry-processing techniques rather than solution applications. Cost will be on the order of $1,000,000.

5) In-Flight Processing - Emphasis should be placed on a continuous program to develop in-flight processing equipment as new laboratory technology becomes available, inasmuch as this area is currently being neglected. Cost will be on the order of $500,000 per year.

[illegible]

... 2 to 4 years ... [illegible]
... involving interpret... [illegible]
... IR, and other sens... [illegible]
... photography.

(b) Targeting and Cha... [illegible]
...arting from sensor data are ... [illegible]
...geting and charting are ... [illegible]
...cation and location of obje... [illegible]
...ography in a variety of for... [illegible]

Light

the 90-in.

6X to 8X.

flicker, and

data. Present

on a multi-channel

as IR, radar, and

frames within a

data matrix recorded

[illegible]

lengths in [illegible] spectra. The [illegible] other targets [illegible] length to [illegible] the density of the [illegible] collected imagery.

SECRET

[illegible]

1. [illegible]

2. [illegible]

[illegible] development of [illegible] bility for large-[illegible] targeting work.

Techniques also [illegible] ing devices to [illegible] than 1 micron. How[illegible] controls required to [illegible] rapidly reaching pra[illegible] the weakest element in [illegible] nature.

SECRET

[illegible]

[illegible]

... stable ... [illegible]

with a high ... [illegible]

... slopes up to ... [illegible]

as well as ... [illegible]

in this type equipment. [illegible]

b. SIGINT Data Extraction [illegible]

Extraction of information [illegible] involves several concepts [illegible] the sensor, the type of sign[illegible]

[illegible]

Because of the high dens[illegible]
important to provide [illegible]
to reduce the amount of [illegible]
primarily manual, with [illegible]

[illegible]

Trends

The trends discussed in [illegible] of the interpreter to [illegible] with the aided-manual [illegible] 1975 time frame. On [illegible] logically will arrive at [illegible]

[illegible]

(b) Targeting and Cha[illegible] [illegible] in interpretation hav[illegible] [illegible] targeting and cha[illegible] [illegible] are expected to fo[illegible] [illegible] automative image-con[illegible] support of both the interpre[illegible] [illegible] developing in sensor [illegible] [illegible] for greater exploitation [illegible] [illegible]/charting purposes. Im[illegible] [illegible] proficiency will apprec[illegible]

[illegible]

[illegible]

... conveyed to ...

The growing requirement ... increased accuracies in ... much more complex faci... continue for further progr...

[illegible]

significant [illegible]
of [illegible]
uous [illegible]
to insure [illegible]
rate [illegible]
Development [illegible]
demonstrated [illegible]
tion of heavily [illegible]
difficult to pre[illegible]
likely to be real[illegible]
than 50 percent of [illegible]
attained by 1970.

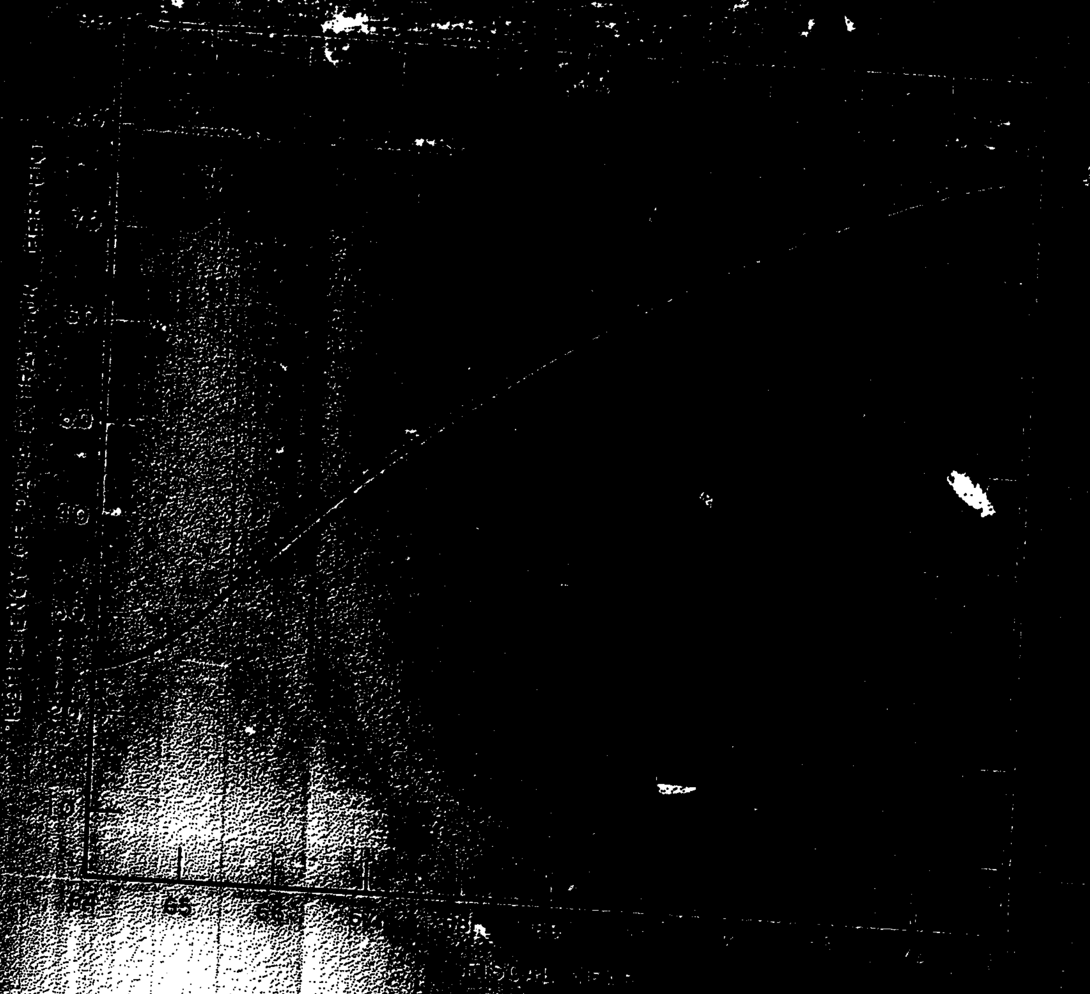


Figure II-17.

3) Intelligence [illegible]

4) Image Analysis [illegible] the 1974/1975 [illegible]

5) Intelligence [illegible]

[illegible] SIGINT [illegible]

Future development [illegible] emphasize [illegible] is presently [illegible] parameters [illegible] are considered. Techniques [illegible] such as radar, frequency [illegible] will be extended to include [illegible]

To improve and expedite [illegible] and analysis, rapid editing [illegible] which will permit sufficient [illegible] bands in mapping signal [illegible]

[illegible]

3) Problems

Image Data Extraction

(1) Manual Techniques - [illegible]

1) Insufficient scientific [illegible] characteristics to inte[illegible]

2) inadequacy of training [illegible] to foster highly profici[illegible]

[illegible]

(3) [illegible] ground systems [illegible] the chief [illegible] area, resources [illegible] personnel, and [illegible]

(b) Targeting and Char[illegible] those outlined above.

[illegible]

[illegible]

... inputs. [illegible]
... application [illegible]
filtering process [illegible]

(3) An accelerated program [illegible]
digital analysis in hi[illegible]
Image density on a fil[illegible]
back to the spectral [illegible]
A highly encouraging in[illegible]

[illegible]

1) [illegible]

2) [illegible]

3) [illegible]

4) [illegible]

5) Rectification [illegible]
data.

6) Rapid stereo and [illegible]
for all sensor [illegible]

7) Rapid production [illegible]

8) Rapid production of [illegible]

[illegible]

b. Summary [illegible]

a. [illegible] Development

(1) [illegible]

1) [illegible]

(2) [illegible]

1) [illegible]

2) Techniques and [illegible] speed and accuracy [illegible] charting operations [illegible] ing, cartographic [illegible] network adjustment, [illegible] image correlation, [illegible] on the order of $2,0[illegible]

SECRET

II-[illegible]

[illegible]

b. Advanced Development [illegible]

[illegible]

1) [illegible]

2) [illegible]

3) [illegible]

4) [illegible]

5) [illegible]

[illegible]

1) [illegible] and funding [illegible] useful [illegible] should provide [illegible] and equipment [illegible] well as document [illegible] ability tests [illegible] ments. Required [illegible]

2) A variety of equipment [illegible] initiated to signifi[illegible] data production cycle [illegible] developments as carto[illegible] ment, universal stereo[illegible] point devices, rectifi[illegible] etc. Funds required [illegible]

3) Component development [illegible]

(b) [illegible]

1) [illegible] digital measuring devices [illegible] coding techniques [illegible] development of [illegible] Typical problems [illegible] equipment and operating [illegible] Evaluation of [illegible] tion, and [illegible] the order of [illegible] per year.

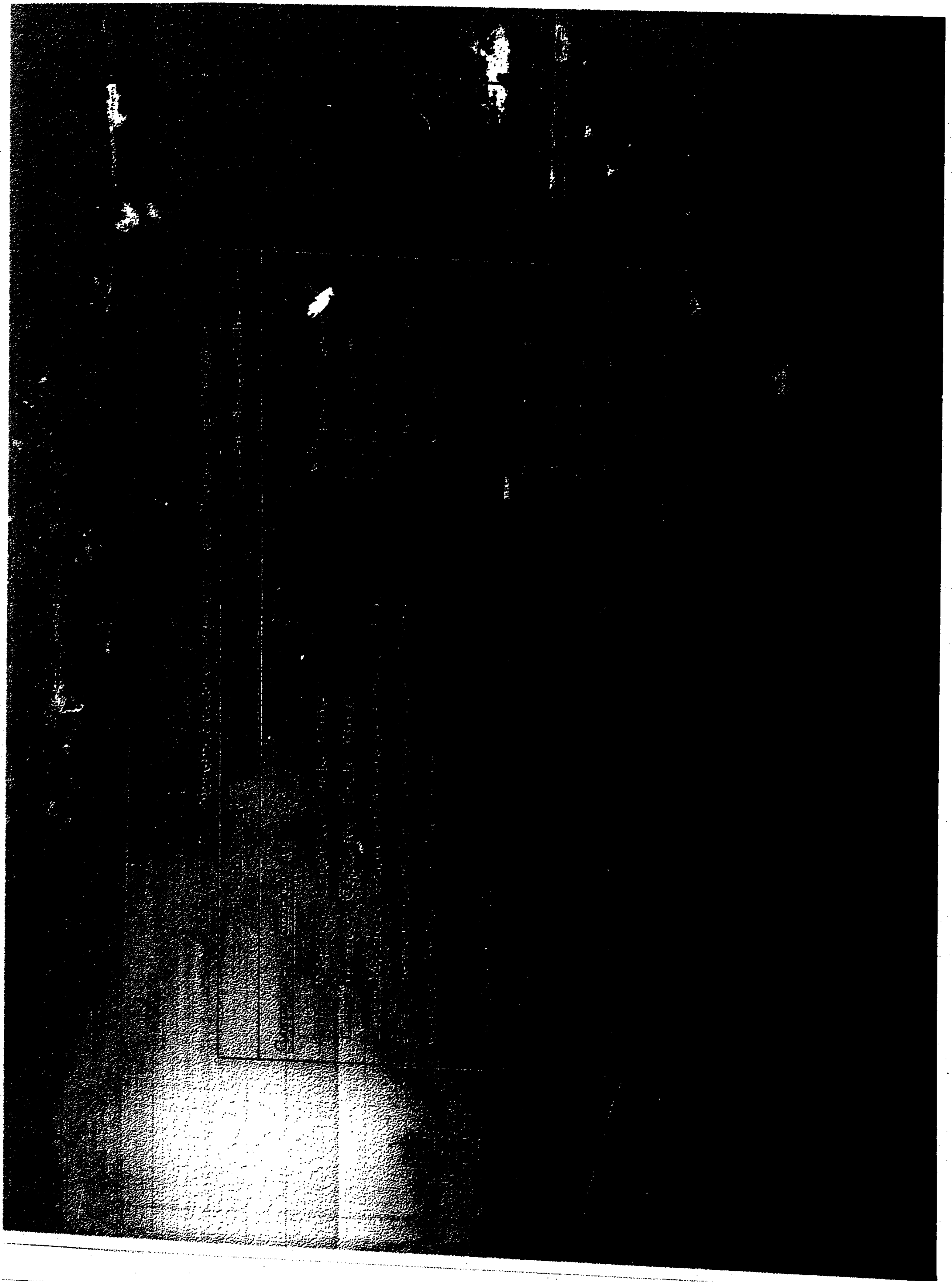
2) Development and evaluation [illegible] techniques would be [illegible] needed [illegible]

[illegible]

[illegible]

[illegible] languages, or the means [illegible] machine, are in use.

Preparation and error co[illegible] account for the largest [illegible] suming function is comput[illegible] tions. A relatively small [illegible] querying the files or prod[illegible] systems efficient utiliza[illegible] sized, usually at the expense [illegible]



[illegible]

... all cases the ...
... system are ...

(b) Input Processing ... a large amount of ... are embedded in English ... amenable to machine processing ... formatting, and key punching ... require substantial error ... times required to accept a ... [illegible]

[illegible]

[illegible] used more extensively [illegible] the contingencies of query [illegible] specification of graphing [illegible] examine the results in one or [illegible] graphing method can be [illegible] control capability appears to [illegible] of graphical products.

Figure II-19. Typical

Figure II-20. Data-Re[illegible]

SECRET

[illegible]

[illegible]

[illegible]

[illegible] manually [illegible]
system called Walnut also [illegible]
search is performed by an [illegible]
accomplished by a device that [illegible]
film store onto aperture-[illegible]

The Strategic Air Command [illegible]
employ MINICARD, among other [illegible]
chip system where each 16-mm [illegible]
reduction ratio together with [illegible]
and expensive system includes [illegible]
and reproducing chips.

SECRET

[illegible]

several facets, such as, [illegible]
dates of events or of [illegible]
[illegible] indexing is performed [illegible]
some encouraging develop[illegible]

Examination of the techniques [illegible]
activities for indexing, fil[illegible]
the keynote is diversity. [illegible]
and maintained locally. The [illegible]
only differences in the kinds [illegible]

[illegible]

2. Trends

[illegible]

[illegible] On-line query stations [illegible]

3. Dissemination

The problem of [illegible] is closely related to [illegible] In both cases the [illegible] availability. Thus, the [illegible] directed toward retrieval [illegible] dissemination problems.

A modest amount of experiment[illegible] techniques has generally [illegible] users specify their needs in [illegible] tem such as the ISC and/or [illegible]

[illegible]

b. Data Storage

A major long-term trend [illegible] less money." Whereas [illegible] ization of the relatively [illegible] to shift in favor of [illegible] reflected in the use of [illegible] puters distributed throughout [illegible] the system.

[illegible]

(not shown on Figure [illegible] capacity and high [illegible] read-only memory.

A point of some concern is [illegible] increasing, "mass-memory [illegible] ondary storage devices. [illegible] access to very large data [illegible] central processor, in that [illegible] for access to the secondary [illegible] predominantly of this type it [illegible] processor.

Figure II-21. Com[illegible]

[illegible]

... on film and di[illegible]
conventional projectors.

Although several associat[illegible]
is not expected that these [illegible]
processing despite the fa[illegible]
Reasons constituting the ba[illegible]

1) Most of the function[illegible]
   can be accomplished [illegible]
   memories at comparabl[illegible]

Table III-6. Projected State-of-the-Art, Data Processing Equipment

2) Associative memories [illegible]

3) Associative memories [illegible]

[illegible]

Adaptive or "self-organizing" [illegible] applications to [illegible]

(2) [illegible]

[illegible]

[illegible] each item [illegible] magnetic-disc files or [illegible] more direct access to [illegible] accomplishment is to use [illegible] "network structures" to [illegible] "network structures" will [illegible] processing techniques to [illegible] Dynamic allocation of both [illegible] necessity.

Table III-[illegible]. Projected State-of-the-Art Data Processing Techniques

Technique	[illegible]	State-of-the-Art [illegible]	[illegible]	State-of-the-Art [illegible]	[illegible]
Programming					
Languages	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Program Compilers	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

[illegible]

[illegible] contents of the [illegible]
most potential is to [illegible]
and thereafter employ th[illegible]
questions about the cur[illegible]
in formulating procedure [illegible]

The goal of conciseness can [illegible]
new terms to the machine. [illegible]
name to some composite colle[illegible]
avoid having to itemize them. [illegible]
reports could be defined and th[illegible]

Once [illegible] data systems [illegible] [illegible] of [illegible] [illegible] conventional [illegible] [illegible]

Various [illegible] [illegible] [illegible]

6. Object Storage

Although there may be some [illegible] toward community-wide [illegible] [illegible] [illegible] minutes.

Although [illegible] [illegible] numbers of small [illegible] [illegible]

[illegible] points of major emphasis [illegible] and lower system cost.

The cost of "integral-index" [illegible] "accession-number" equipment [illegible] the advantage of integral-index [illegible] dex search is unimportant [illegible] a computer is available. For these [illegible] is expected to predominate in [illegible]

SECRET

Input Processing

A major problem in the [illegible] vestment that is required [illegible] ized files generally require [illegible] than manual files, mechaniza[illegible] in the support staff.

[illegible]

[illegible]

[illegible]

4. Summary

[illegible]

[illegible] technology [illegible] systems is being supported by [illegible] Considerable exploratory [illegible] is being funded at Mitre [illegible] contractors. In addition, [illegible] being funded by other government agencies.

b. Exploratory Development

Important exploratory development efforts in support of information [illegible] acquisition, storage, [illegible] inter-machine [illegible] include:

1) Further analysis of [illegible] for [illegible] in [illegible] and [illegible] and syntactic [illegible]

2) All-font optical print reading

3) Improved techniques for [illegible] of [illegible] materials

4) Man/machine methods for [illegible] and [illegible] of graphic displays

5) Information-processing aids to photo interpretation

6) Self-teaching [illegible] reading (cf. Section III.C.2.b(2))

7) Data structures for use [illegible] in on-line systems (cf. Section III.C.2.b([illegible]))

8) Solutions to the "mass memory gap" problems (cf. Section III.C.2.b([illegible]))

9) Methods of dynamic storage [illegible] organization of documents, [illegible] of [illegible] and query characteristics

10) Meta-languages for [illegible] (cf. Section II.C.2.b(2))

11) Improved techniques for handling "[illegible] queries" (cf. Section II.C.2.b(2))

12) Inter-machine query [illegible] in [illegible] and geographically distributed computer networks

13) Linguistics in general

14) Methods for measuring performance of information handling, dissemination, and retrieval systems.

(3) [illegible]
[illegible]

Funding required [illegible]
[illegible]

b. Advanced Development

Advanced development [illegible]
storage, and retrieval [illegible]

(1) Development of [illegible]

(2) [illegible]
[illegible]

(3) Multi-[illegible]

(4) [illegible]

(5) [illegible]

(6) Computer [illegible]
[illegible]
[illegible]

(7) Multiple [illegible] of [illegible] systems.

(8) Advanced magnetic [illegible]

(9) Advanced memory [illegible] devices.

Funding required for [illegible] will be of the order of [illegible]
years.

SECRET

SENSOR INTEGRATION

[illegible]

[illegible]

[illegible]

Consideration is [illegible] data manipulation [illegible]

Techniques for providing [illegible] are now being explored. [illegible] electro-optical sensors [illegible] tude, whereas radar range [illegible] bining these data with [illegible] ELINT and COMINT techniques [illegible] Gross location of emitters [illegible]

[illegible]

A terrain-profile recorder [illegible] flight path to an accuracy [illegible] Electronic distance-measuring [illegible] Ranging (SHIRAN) will record [illegible] to 110 ft in 500 mi. The [illegible] the Hypernas II-b inertial [illegible] and air data computer. When [illegible] correlated on the ground, the [illegible] of the overflown area to first-order [illegible]

SECRET [illegible]

II-[illegible]

[illegible]

so that the human may [illegible]
only. Transmission to [illegible]
tems except coherent [illegible]
recording, or in near [illegible]
ing or filtering has been [illegible]
will still require at least [illegible]
raw data and for processing [illegible]
posite displays for human [illegible]

[illegible]

Problems

Problem areas [illegible]

1) [illegible]

2) Near-real-time [illegible]

3) Reduction of [illegible]

4) Maximum man/machine [illegible]

5) Automation of [illegible]
sensory data for [illegible]

SECRET

Figure II-22. Ap[illegible]

6) Integration of [illegible] systems.

7) [illegible]

8) [illegible] analysis. [illegible]

9) Calibration of sensors [illegible]

10) Choice of sensors [illegible] providing data [illegible] basic [illegible]

c. [illegible]

d. [illegible]

[illegible] should be [illegible]

1) [illegible]

2) [illegible] analysis and of man/machine [illegible]

3) Automation of [illegible] sensor data.

4) Integration of [illegible] product.

5) Integration of naviga[illegible] determinations.

6) High-speed data-reductio[illegible]

[illegible] work in the above area is [illegible] manpower should be increased by at [illegible] equivalent to $1,000,000.

SECRET

5. Advanced Developments

[illegible]

1) [illegible]

2) [illegible] period [illegible] per year [illegible]

3) Development of [illegible] [illegible]

[illegible] SENSORS

[illegible]

[illegible]

1) [illegible]

2) Seismic techniques

3) [illegible]

4) [illegible]

5) [illegible]

6) [illegible]

7) [illegible]

8) [illegible]

9) [illegible]

10) [illegible]

11) [illegible]

12) High-frequency [illegible]

13) Cosmic noise [illegible]

14) Atmospheric fl[illegible]

15) Direct optical vi[illegible]

16) IR/UV radiometry [illegible]

2. Recommendations

[illegible]

[illegible]

[illegible] to produce [illegible] dimensions, a number of [illegible] customary [illegible] line dispersion [illegible] probably is the property [illegible] high quality optical glass, [illegible] noted properties and the [illegible] glass is required to produce [illegible] and performance characteristic[illegible]

The only remedy is to have at [illegible] source of such glass within the [illegible] kinds of optical glass are avail[illegible] sizes, the techniques for produ[illegible]

SECR[illegible]

[illegible]

Several phases [illegible]

1) Applied research [illegible] ... small and large [illegible]

[illegible]

[illegible]

b. Optics Science Facility

The proposed facility is an [illegible] centered around a large 100-in. [illegible] a capability for performing [illegible]

SECRET

[illegible] and guided systems. [illegible]

[illegible]

This facility is to provide [illegible]

[illegible]

A part of this [illegible]

[illegible]

This installation is intended for [illegible] extraction techniques [illegible] systems. [illegible] laboratory-type [illegible] controlled photo processing, [illegible] ation, technical intelligence analy[illegible] Cost of this facility will be [illegible]

SECRET

[illegible]

(1) The Eglin [illegible]
environmental [illegible]
swamps, [illegible]
that are conducted [illegible]
Commandos on the [illegible]
ities of insurgen[illegible]
Deficiencies for [illegible]
two categories of [illegible]
vehicles, small bo[illegible]
instrumentation su[illegible]
permit flare drops [illegible]
delta of the Choct[illegible]
period of time to [illegible]
Delta in South Viet [illegible]

(a) [illegible] Air Force Base, [illegible] ... [illegible]

(b) [illegible] Air Force Base, [illegible] ... [illegible]

(c) A location in the [illegible] mountainous terrain [illegible] most likely to [illegible] place in close proximity [illegible] is preferable, [illegible] targets can be [illegible] foothills to mountains [illegible]

Costs for establishment of the [illegible] ranges will be on the order of [illegible]

c. Low-Altitude Photogrammetric [illegible]

In order to avoid early detection [illegible] aircraft must penetrate enemy [illegible] naissance and weapon systems [illegible] buffeting and high-g forces in the [illegible]

APPENDIX A

GLOSSARY

Actinic light - That portion of the electromagnetic spectrum to which a material is sensitive.

Angular resolution - The angle subtended at the sensor by the ground resolution.

Apodization - A technique wherein transmission at the aperture is modified, usually by circular transmission filters, in such a manner that transmission varies gradually from the center to the edge, resulting in a diffraction pattern which has a higher percentage of the total energy in the center spot and a lower percentage in the diffraction rings. However, the size of the center spot becomes slightly larger, which in some cases greatly increases the resolution of low-contrast detail.

Area search - Reconnaissance performed for detecting and identifying potential targets.

Aspheric - A term used to describe an optical surface which is neither a section of a sphere nor of a plane.

Beverage antenna - A long-wave low-frequency straight-line antenna placed close to the ground. It normally is used in approximately 3-mi lengths.

Bolometer - Device whose resistance changes in accordance with changes in temperature used in the measurement of microwave energy. It contains a resistive element, the resistance of which changes as a result of heating by r-f power.

Catadioptric optic systems - Optical systems which contain both reflective (mirror) and refractive (lens) elements.

COBOL - Common Business Oriented Language

Cold war - The use of political, economic, technological, sociological, psychological, and military measures short of overt armed conflict involving regular military forces to achieve national objectives. Cold war includes periods of increased international tension, accelerated paramilitary activities, and increased activity by military forces.

---

*JCS definition

Calibration - Activity whereby information is accumulated. For example, documents may be collected or sensors may be used to [illegible] information on a [illegible] mission. [illegible] is not confined to gathering information by sensors [illegible] a mobile [illegible] staging or assembly area [illegible].

Counterguerrilla warfare - Offensive operations conducted by armed forces and/or nonmilitary agencies of an established government and/or its allies against guerrilla forces.

Counterinsurgency (COIN) - The entire range of military, paramilitary, political, economic, psychological, and civic actions taken by or with the government of a nation to defeat insurgency (primarily associated with cold war).

Cryostat - A device used to lower temperature by passing a gas at high pressure through a small aperture into an area of lesser pressure.

Data base - An all-inclusive body of information which serves as a background against which new information may be compared, or which, through constant refinement, serves as a solid point of departure for planning.

Decibel milliwatts (dbm) - 1 dbm = 10 log (power out)/(1 milliwatt power in).

Decibel watts (dbw) - 1 dbw = 10 log (power out)/(1 watt power in).

Ephemeris (pl. ephemerides) - A table giving the position of natural or artificial heavenly bodies as a function of time.

Exploitation - Correlation of information from intelligence records (i.e., locations shown in photos, signal analysis, ELINT emitter positioning) with other available data for synthesis in the production of an intelligence estimate.

Extraction - From the standpoint of intelligence functions extraction constitutes the first phase or task in obtaining information from a record to be used as a basis for subsequent exploitation and analysis.

FORTRAN - An acronym for "Formula Translation" (IBM common algebraic computer language).

Frisket - A sheet stretched in a frame with parts cut out to lay over a prepared form allowing only certain parts to be printed.

General war - Armed conflict between the major powers of the communist and free worlds in which the total resources of the belligerents are employed and the national survival of a major belligerent is in jeopardy.*

Ground resolution - The size of the smallest object on the ground that can be distinguished on a sensor record by an interpreter.

Ground truth - Data which describes the true situation on the ground at the time that aerospace-borne sensor data is collected. This information consists of reflectance, emission, and description of target and background as well as meteorological data.

Guerrilla warfare (GW) - Combat operations conducted generally in enemy-held territory by predominantly indigenous forces on a military or paramilitary basis to reduce the combat effectiveness, (industrial, economic, political, and military war potential), and morale of the enemy.*

Hard copy - A finished copy - Directly readable.

Identification - The degree of detail that presents determination of the general characteristics of an object and the function that may be performed.

Imbibed emulsions - Photographic materials which include light-sensitive components and most of the required developing chemicals.

Intelligence - The product resulting from collecting, evaluating, analyzing, integrating, and interpreting all available information which concerns one or more aspects of foreign nations or of areas of operations and which is immediately or potentially significant to military planning and operations.*

*JCS definition

Intensity, level of -

Phase I. This phase ranges from circumstances in which subversive activity is only a potential threat (general mode), latent, or already incipient, to situations in which subversive incidents and activities occur with frequency in an organized pattern. It involves no major outbreak of violence or uncontrolled insurgent activity.

Phase II. This phase is reached when the subversive movement, has gained sufficient local or external support to initiate organized guerrilla warfare or related forms of violence against the established authority.

Phase III. The situation moves from Phase II to Phase III when the insurgency becomes primarily a war of movement between organized forces of the insurgents and those of the established authority.

Laser - Light amplification by stimulated emission of radiation.

Limited war - Armed conflict short of general war, exclusive of incidents involving the overt engagement of the military forces of two or more nations.*

Mapping and geodesy - The collection of high-accuracy reconnaissance data for producing accurate maps of actual or potential battle areas and for accurate target location. The geodetic aspect usually implies refinements such as location of bench marks to establish datum relationships, gravity anomaly measurements, etc.

Meta-language - A language used to describe other languages and the translations between them.

Mission - The broad purpose or basic charter of an organization.

Monobath web - A porous carrier material which stores a chemical solution that will develop and fix a photographic image on contact.

Nanosecond - A measurement of time equal to 10^{-9} seconds.

Neutralization - Action taken against an enemy element rendering it incapable of performing its mission. Neutralization includes killing or destroying.

---

*JCS definition

SECRET

Octave - The interval between two sounds having a basic frequency ratio of two.

Photographic receptor - A material which is sensitive to light and on which is [illegible] [illegible] recorded.

Real time - A measurement of time for an action or reaction which is, or approaches, instantaneous.

Recce-strike - Implies a combined mission of reconnaissance and strike over the attacking enemy territory beyond and attack appropriate targets. A modified version includes performing reconnaissance of targets supposedly already hit and striking again if necessary.

Reconnaissance - A mission undertaken to obtain, by visual observation or other detection methods, information about the activities and resources of an enemy or potential enemy; or to secure data concerning the meteorological, hydrographic, or geographic characteristics of a particular area.*

Reconnaissance, area search - Reconnaissance performed for detecting and identifying potential targets.

Reconnaissance missions -

Area Search - Reconnaissance performed for detecting and identifying potential targets.

Operational - Reconnaissance performed in sufficiently fine detail to permit identifying objects previously detected in areas of interest.

Objective - Reconnaissance performed to provide the detail necessary to permit analysis of specific objects, including their technical aspects.

Reconnaissance system - All aspects of reconnaissance from data acquisition or collection through data processing, transmission and extraction.

Reconnaissance, tactical air - The collection by aerial vehicles of information on terrain, weather, electronic and communications emissions and on air, sea, and ground forces or installations, lines of communications, and target status as required to plan and conduct tactical military operations.

---

*JCS definition

Reconnaissance, weather - Reconnaissance to obtain weather data over areas where weather reports from other sources are not available or to obtain special reports of weather conditions along the routes to and in the vicinity of targets for planned air operations [illegible]

Satellite signature analysis - The use of radar information such as radar return signal amplitude, phase difference, and polarization to determine satellite size, body motion, and mission.

Special warfare - Special warfare encompasses counterinsurgency operations, counterguerrilla activities, unconventional warfare, and psychological warfare. Although the forces and air operation associated with each type of activity are often similar, counterinsurgency is primarily associated with cold-war conditions, whereas unconventional warfare is primarily associated with limited-war or general-war conditions. Psychological warfare is a most important factor throughout the entire spectrum of cold, limited, and general war.

Squint angle - The angle between the two major lobe axes of a lobe-frequency ratio of two.

Squint mode - The angular difference between the axis of an antenna radiation and a selected geometric axis, such as the axis of the reflector.

Strategic warning - A notification that enemy-initiated hostilities may be imminent. The time element may vary from minutes to hours, days, or more.

System - A composite of personnel, equipment, skills, and techniques intended to perform and/or support an operational role. A complete system includes vehicles and subsystems, related facilities, sensors, equipment, material, services, and the personnel required for its operation to the degree that it can be considered a self-sufficient unit in its intended operational and/or support environment.

Tactical warning - Notification that the enemy has initiated hostilities. Such warning may be received any time from the launching of the attack until it reaches its target.

Target description - A single characteristic of the reconnaissance data that assists in describing the target for [illegible] recognition and identification.

Targeting - The selection of [illegible] based upon information [illegible] through reconnaissance.

Task - From a major-military-organization standpoint, a task is an assignment entrusted to that organization. From the standpoint of a major element within the organization, a task is the step-by-step procedure whereby a certain function may be accomplished.

Technical intelligence - The evaluated end product resulting from the assessment of information collected by [illegible] means concerning the progression of the state-of-the-art in all technical disciplines being pursued by a country.

Unconventional warfare - Includes the three interrelated fields of guerrilla warfare, evasion, escape, and subversion against hostile states. Unconventional warfare operations are conducted within enemy or enemy-controlled territory by predominantly indigenous personnel usually supported and directed in varying degrees by an external source and are primarily associated with limited-war or general war conditions.

Up-converter - The type of parametric amplifier which is characterized by the frequency of the output signal being greater than the frequency of the input signal.